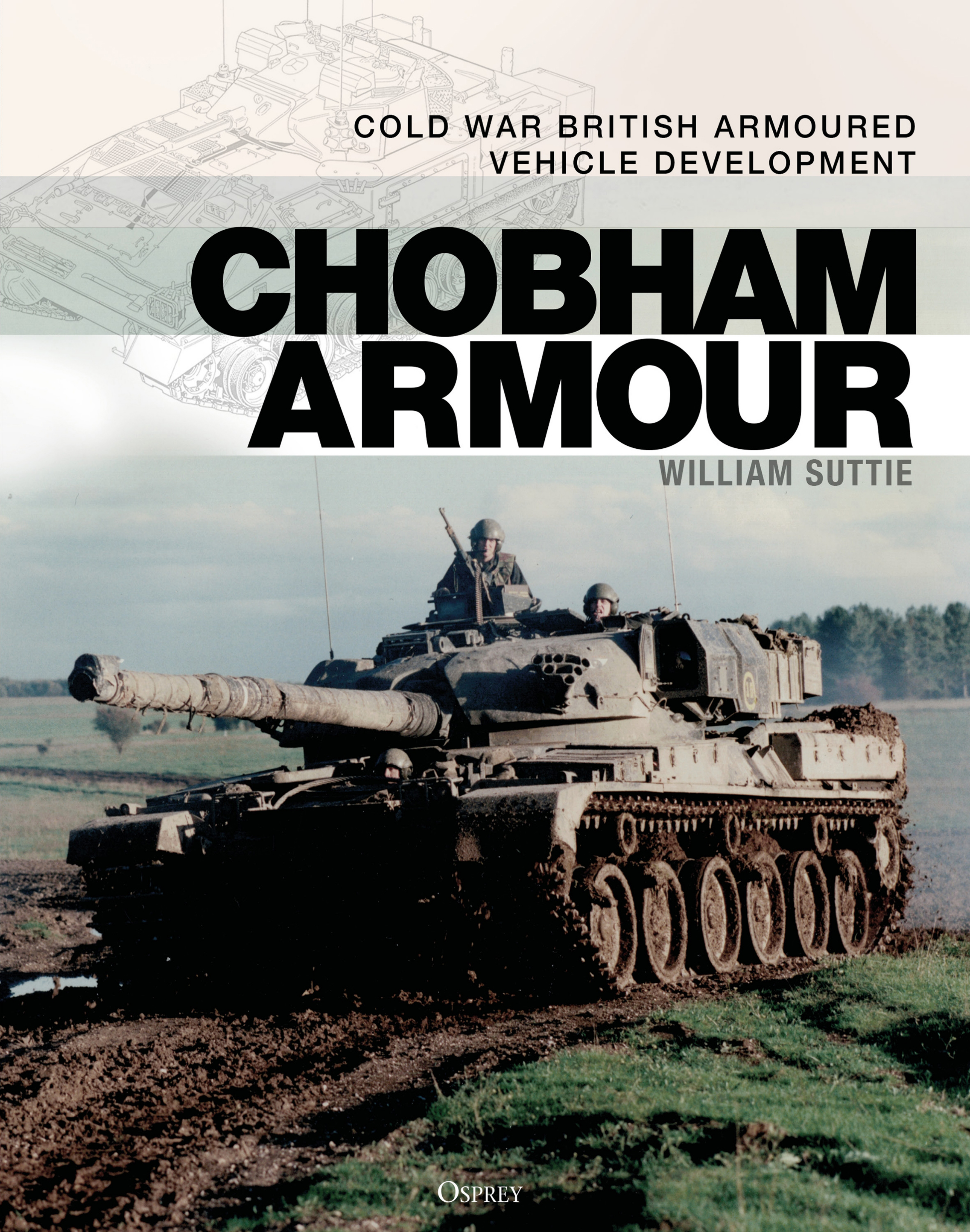
COLD WAR BRITISH ARMOURED
VEHICLE DEVELOPMENT

CHOBHAM ARMOUR

WILLIAM SUTTIE



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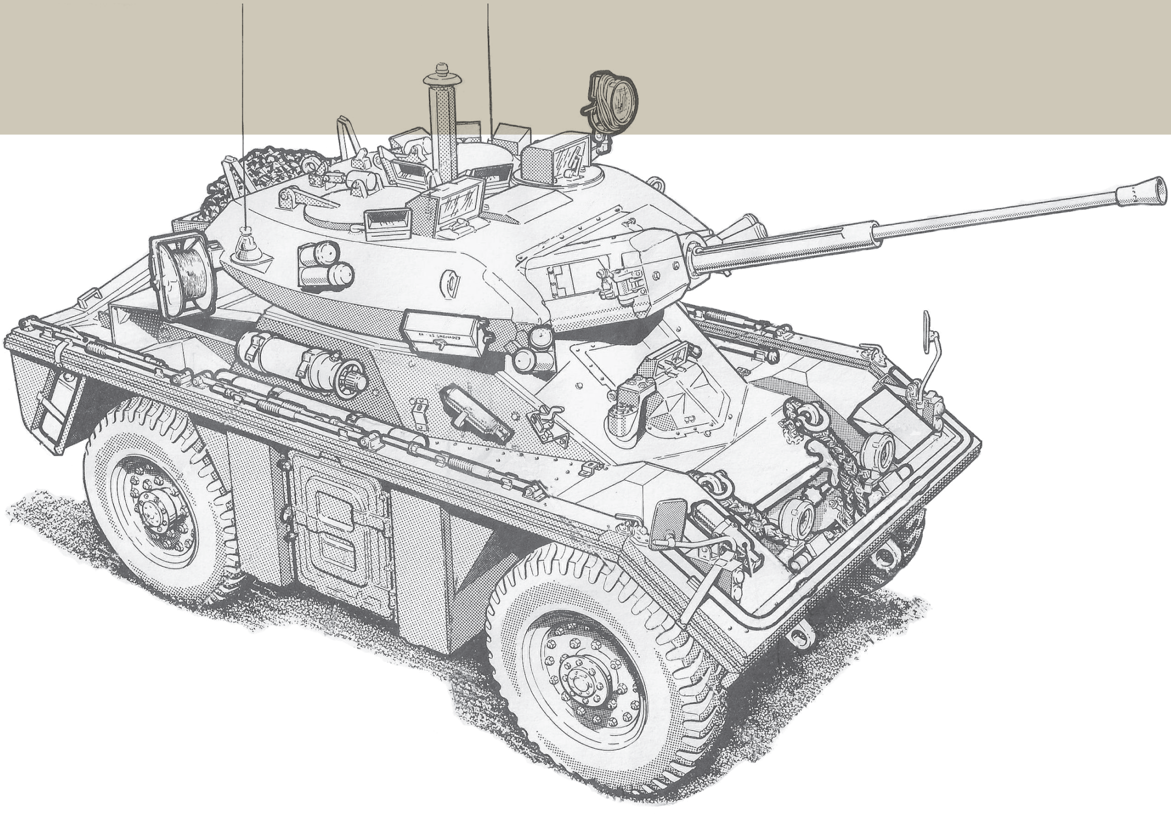

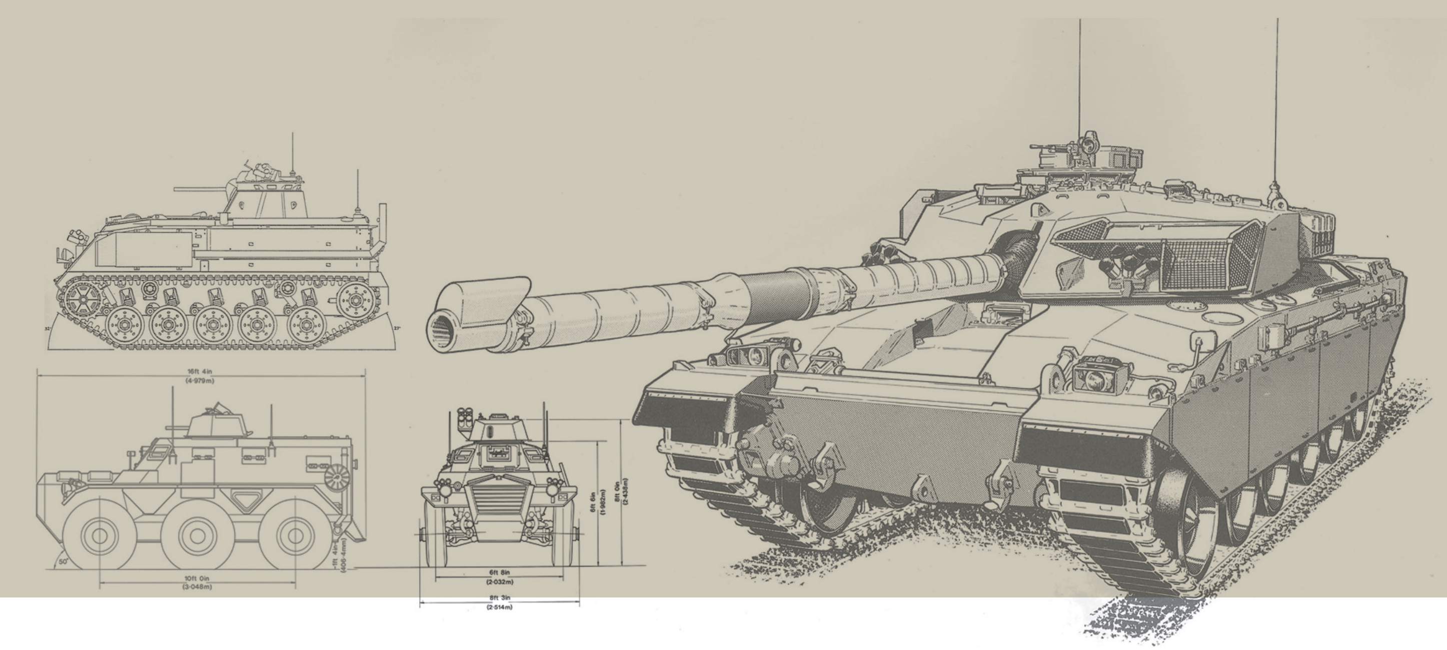
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(4·979m)
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8ft 3in
(2·514m)

CHOBHAM ARMOUR

Cold War British Armoured Vehicle Development

William Suttie

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CONTENTS

Acknowledgements 7

Introduction 9

PART 1: Main Battle Tank Development 13

- Centurion 14
- Conqueror 43
- Countering the Soviet Tank Threat 54
- Chieftain 69
- Novel Concept Studies 98
- UK/German Future Main Battle Tank 111
- MBT80 and the 4030 Programme 115
- Challenger 1 127
- Challenger 2 144
- Future Concept Studies 150

PART 2: Medium and Light Tracked AFV Development 167

- Light Tanks and Combat Vehicle Reconnaissance (Tracked) 168
- Carriers and Armoured Personnel Carriers 194
- Other Light and Medium Tracks Concept Studies 240

PART 3: Wheeled AFV Concepts and Development 249

- Saladin and Saracen 250
- Ferret 256
- Wheeled Armoured Vehicle Reconnaissance Concepts 261
- Fox and Vixen 263

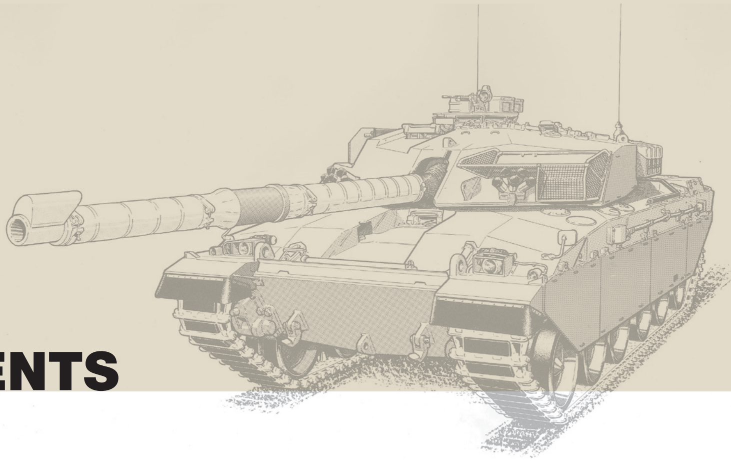
PART 4: Other British Armoured Vehicles of the Cold War Era 269

- 1-Ton Armoured 4x4 Humber 270
- FV180 Combat Engineer Tractor 272

SP70: 155mm Self-Propelled Howitzer 274
Saxon 276
Vickers Main Battle Tanks 277

APPENDICES

ANNEX A: List of FV Numbers 280
ANNEX B: Centurion Data 289
ANNEX C: Chieftain Data 292
ANNEX D: Challenger 1 Data 295
ANNEX E: CVR(T) Data 297
ANNEX F: FV430 Series Data 302
ANNEX G: Warrior Data 305
ANNEX H: Saladin Data 308
ANNEX I: Saracen Data 310
ANNEX J: Ferret Data 311
ANNEX K: FV721 Fox Data 313
Index 314



ACKNOWLEDGEMENTS

I had the privilege of working at the Armoured Vehicle Research and Development Establishment on Chobham Common for over 20 years, up until most vehicle-related activities there stopped in 2003. The significance of the establishment encouraged me to write a history of the site, which I called *The Tank Factory* – the name used by locals when referring to it. When carrying out research into the history of the site I came across many reports, photographs and information about the concepts and vehicles developed there. Therefore, as someone with a lifelong interest in armoured fighting vehicles, I decided to write a detailed book focused on the design and development of vehicles at Chertsey through the period that was mainly characterized by the Cold War. I have endeavoured to cover both the resulting battle-winning vehicles developed there and also the wide range of interesting proposals and concepts that never made it as far as prototypes, let alone production.

Recognizing that there are many excellent books available on the military vehicles used by the British Army, I have tried to avoid just repeating information that is already published, but instead I focus on using unpublished information, especially that from official sources in order to ensure that the information presented is as accurate as possible. I have also tried to use pictures which have not been published before.

I would like to thank the UK Ministry of Defence and the Defence Science and Technology Laboratory (Dstl) for giving approval for this book, the staff at the Bovington Tank Museum for their support, and ex-Chertsey staff for their help and encouragement. Special thanks go to Steve Smith at Dstl for his review of the book and also to Angela, Gemma and Karina for their encouragement.

Finally, I would like to acknowledge all the men and woman of the British Army who fought in these vehicles as a 'force for good' throughout the world.

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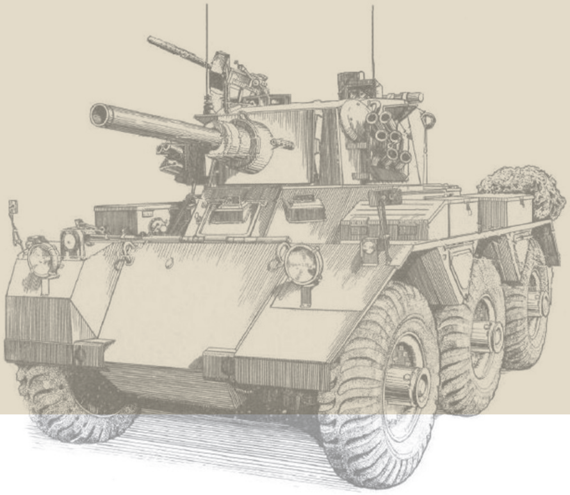
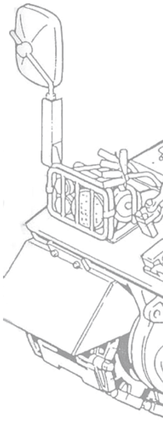


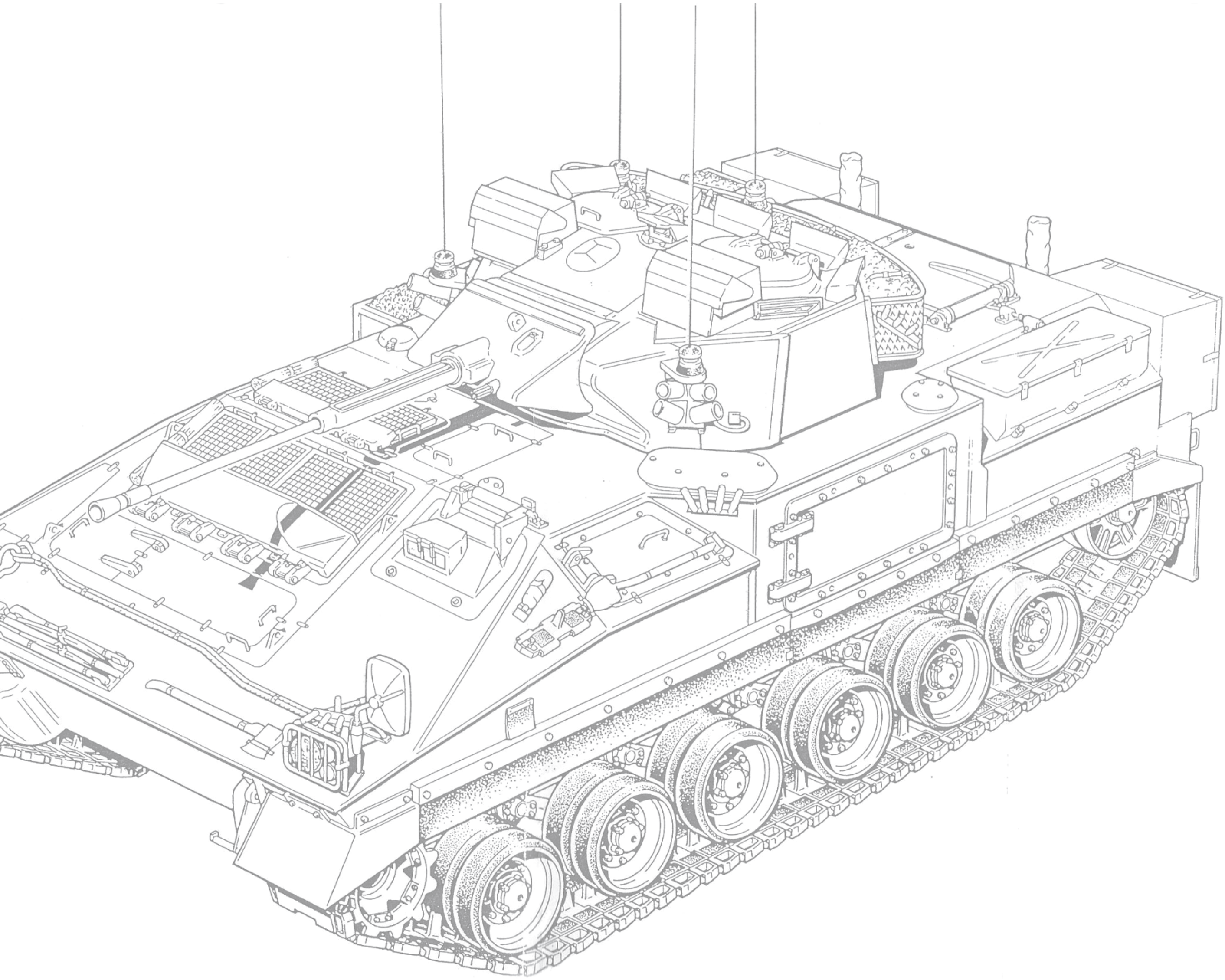
INTRODUCTION

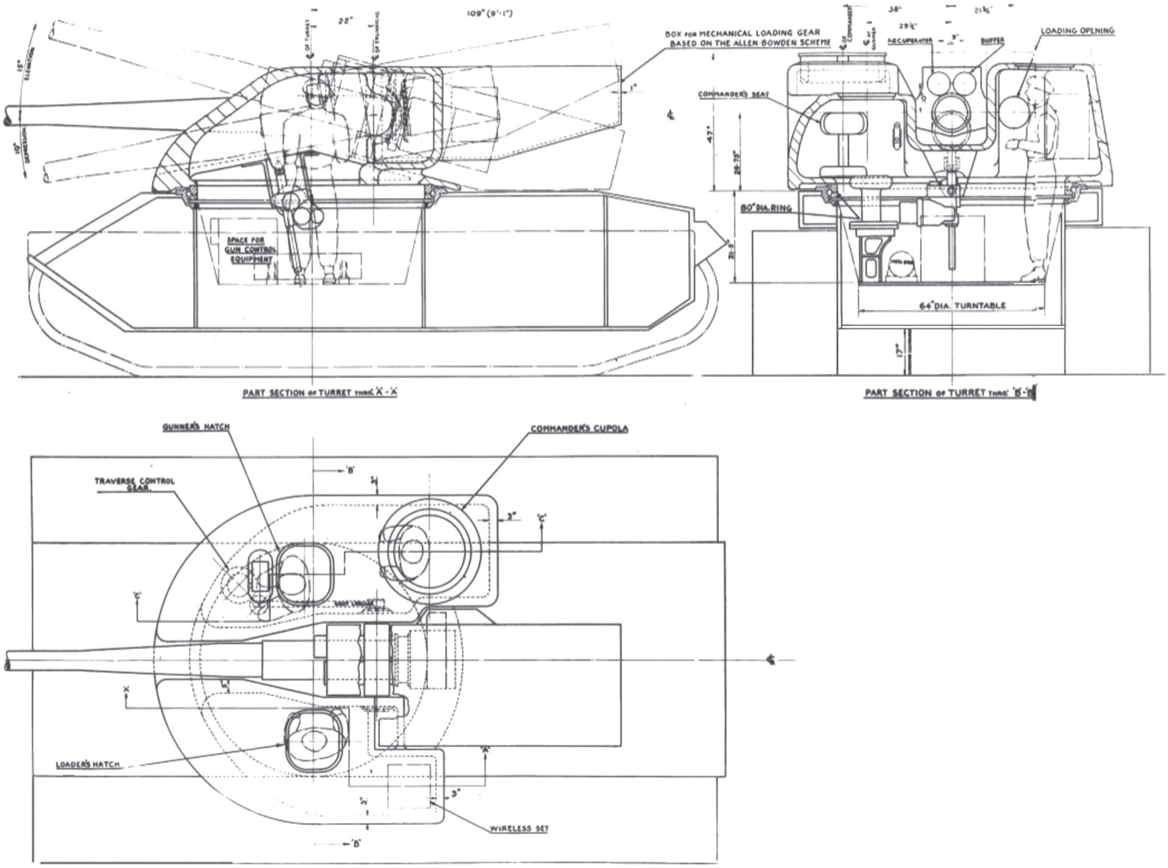
Chobham armour is the common name often applied to a groundbreaking armour technology which was developed at a Ministry of Defence site on Chobham Common. That armour transformed the design of NATO tanks from the mid-1970s onwards. The term Chobham armour could also be applied to the British Army armoured vehicle fleet through the Cold War era, as it was at the same Chobham site that these vehicles, and key technologies, were developed. A centre for military vehicle design, development and testing was established on Chobham Common in 1942. It became the design authority for British military vehicles, a responsibility it held until 1982 when this was transferred to industry. In practice this meant it was responsible for the design and development of most British military vehicles, principally armoured vehicles. It also generated technical specifications for design, test and acceptance of other military vehicles and related equipment, supported suppliers in industry with platforms development and undertook rigorous testing as part of vehicle development, assessment and user acceptance. It went through various name changes from its roots as the Department of Tank Design (DTD), through the Fighting Vehicles Design Department (FVDD), the Fighting Vehicles Research and Development Establishment (FVRDE) and the Military Vehicles and Engineering Establishment (MVEE). From 1984 until it closed in 2002 it was amalgamated with other Ministry of Defence establishments to become part of a larger organization initially coming under the Royal Armaments Research and Development Establishment (RARDE), the Defence Research Agency (DRA) and the Defence Evaluation and Research Agency (DERA) before finally being split to form constituent parts of the government Defence Science and Technology Laboratory (Dstl) and the privatized QinetiQ. Soon after this final reorganization it was closed as a military vehicle research establishment. Throughout its life the staff who worked there and the other government and industrial organizations that worked with the establishment referred to it by its postal address, ‘Chertsey’, and this is the name that is used throughout the book to refer to specific activities undertaken at the site.

As well as concept and design work to meet specific army requirements, Chertsey undertook more speculative concept development and the building of test rigs and demonstrators in order to explore the ‘art of the possible’. Not all proposed equipment went into production or even passed the initial concept phase before being cancelled; some reached scale or full-size model status or even prototype phase, but due to changing requirements or budgetary constraints did not progress further. Since the end of World War II all proposed new vehicles and related equipment have been allocated an ‘FV’ number. The full range of the activities at the Chertsey establishment is reflected in the ‘FV’ number list given in Appendix A.

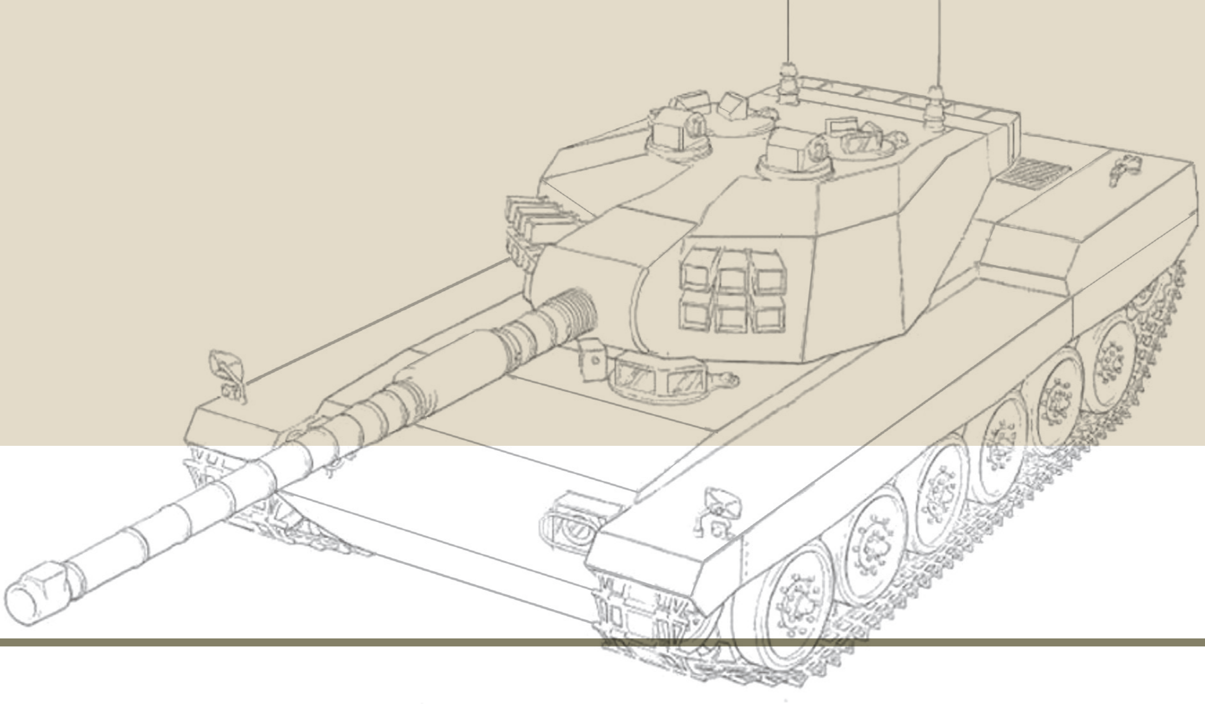
This book focuses on British Cold War Armoured Fighting Vehicle (AFV) design studies and development projects through the work at Chertsey. Arguably these vehicles achieved their intended purpose, which was to help deter a Soviet invasion of western Europe, and so were never required to fight the war they were designed for. However, they have been extensively and successfully used by the British Army in many campaigns including Korea, the Falklands, the Balkans, Kuwait, Iraq and Afghanistan and by other users around the world, proving their battle-winning capabilities.






109" (9'-1")
22"
℄ OF TURRET
℄ OF TRUNNIONS
15° ELEVATION
10° DEPRESSION
BOX FOR MECHANICAL LOADING GEAR BASED ON THE ALLEN-BOWDEN SCHEME
1"
SPACE FOR GUN CONTROL EQUIPMENT
PART SECTION OF TURRET THRO' 'A'-'A'
38"
21¾"
29½"
℄ OF COMMANDER
℄ OF GUNNER
RECUPERATOR
9"
BUFFER
LOADING OPENING
COMMANDER'S SEAT
47"
28·75"
80" DIA. RING
31·5"
64" DIA. TURNTABLE
17"
PART SECTION OF TURRET THRO' 'B'-'B'
GUNNER'S HATCH
COMMANDER'S CUPOLA
TRAVERSE CONTROL GEAR.
'B'
'C'
3"
'A'
LOADER'S HATCH
WIRELESS SET
℄

ABOVE
Split turret concept, one of many schemes considered for the Medium Gun Tank No.2. (Crown Copyright MOD)



PART 1

MAIN BATTLE TANK DEVELOPMENT

ABOVE
Future Tank Concept A, small turreted tank.
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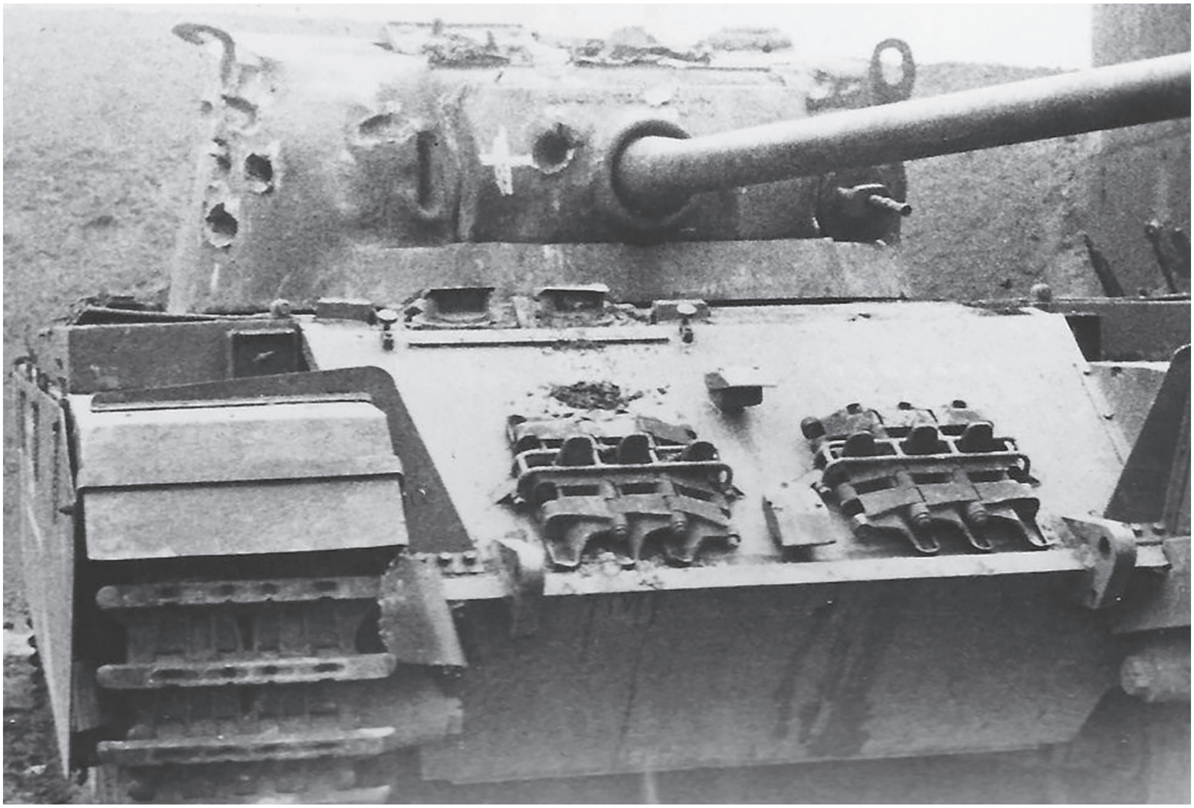
CENTURION



Centurion Mark 1 undertaking armour protection trials. (Crown Copyright MOD)

The first significant post-war armoured vehicle associated with Chertsey was the A41 Centurion tank. Development of this vehicle had actually started at what was then called the Department of Tank Design (DTD) in August 1943 but the first prototypes were delivered too late to see action in World War II. The design and development work was under the direction of Sir Claude Gibb, who had been appointed Director-General of Tank Production that year. It was originally designated as a 'heavy cruiser tank' and the key driver for the tank was the need to overcome the mismatch between the firepower and protection of contemporary German and British tanks. The vehicle requirements were developed by the Army Council Secretariat and were heavily influenced by experience in the Western Desert. The final specification was agreed in November 1943 with the key high-level requirements defined as:

- An armament capable of defeating the German Tiger tank, which was just coming into service, and also able to fire high-explosive (HE) rounds;
- Armour proof against the German 88mm gun;
- Attention to be given to improved mine protection compared with existing vehicles;
- High-agility cross country, but not a high top speed;
- A high-speed reverse gear.

Initially a weight of less than 40 tons was specified in order to conform with existing tank transporter trailers, but this was soon relaxed in order not to compromise the protection levels. Width was to be limited to 126 inches for transport by rail within the United Kingdom and to cross the Bailey bridge. The turret ring was to be as large as possible to support future up-gunning and it was suggested that in the future the 94mm 32-pdr gun could be fitted.

A mock-up of the vehicle was completed in December 1943 and the final specification accepted at the 38th Meeting of the Tank Board on 23 February 1944. The Department of Tank Design worked on the design and development with AEC Ltd who were appointed as Design Parents. The Chief Engineer at AEC was G. J. Rackham who had served as a Tank Corps officer and AEC already had some experience of developing military equipment having been involved in the development of military lorries, armoured cars and flamethrowers. The first mild steel prototype hull was available in May 1944 and was inspected by the Director Royal Armoured Corps on 24 May at AEC's plant at Southall. The Tank Board recommended that 20 prototypes be produced, but the build of these did not start until January 1945. The first full prototype was delivered to Chobham in April 1945, and by May 1945 six prototypes had been made, three at Woolwich and three at the Royal Ordnance Factory (ROF) at Nottingham. On 14 May these were sent to Southampton to be rushed to Germany, but arrived just too late to see action. They had been shipped across to Antwerp and had successfully covered the 400 miles to Schleswig-Holstein on arrival. They remained in Germany until July for field testing, under what was called Operation *Sentry*, before returning to the UK via Calais.

The 20 prototypes that were built had a number of different weapon fits:

- Prototypes 1–5 mounted a 17-pdr main gun and 20mm Oerlikon cannon, plus a machine gun mounted in the rear of the turret;

- Prototypes 6–10 were similar to 1–5, but had no turret rear machine gun;
- Prototypes 11–15 mounted a 7.62mm Coaxial machine gun in place of the 20mm cannon;
- Prototypes 16–20 mounted the 77mm gun as used on the Comet tank.

The 20mm cannon had been proposed as a weapon for defeating towed anti-tank guns, however, it was operated by the loader – distracting him from the main tasks of loading the main weapon and operating the radios. In addition, there was a call from the army for a forward-firing machine gun, since there was no hull-mounted machine gun, which meant the 20mm gun was soon replaced. The initial concepts had Christie-type suspension based on that used on the Comet but with a longer hull and an additional wheel station on each side; however, it was considered inadequate for the heavier vehicle and was soon replaced by Horstmann double bogie wheel assemblies; these were easier to maintain than Christie suspension and simpler to repair following mine damage. The ride was not as good as that provided by Christie suspension but was still assessed to be adequate. One innovation on Centurion was the installation of an 8hp Morris car engine to drive an auxiliary generator; this allowed batteries to be charged and electrical equipment operated without running the main engine.

On its return from Operation *Sentry* in Germany, one of the prototype vehicles was fitted with a 'Canal Defence Light' (CDL) system by the Special Armour Establishment. The CDL was a very bright light source that had been developed during World War II to support night operations when, as well as providing illumination, it was intended to dazzle enemy gunners. The Centurion system was fitted to the left side of the turret so that full weapon functionality was retained; however, it was never fielded.

The layout of the Centurion reflected what became the standard for post-war British Main Battle Tanks (MBTs). Most previous tanks developed during World War II had a five-man crew, with a driver and co-driver or hull machine-gun operator in the hull and commander, gunner and loader in the turret; however, the Centurion had a four-man crew with just a driver in the hull. The driver was located at the front right-hand side of the hull and, unlike previous Cruiser British tanks, was protected by sloped armour. The centrally located turret had a crew of three; the commander and gunner seated in tandem to the right of the gun and the loader to the left. The rear of the hull housed the engine and gearbox which drove the tracks through rear-mounted sprockets. Throughout its service life in the British Army, the Centurion was continuously improved with the Mark 13 being the final version. Full technical data for the main variants of the Centurion gun tank are given in Appendix B.

The main engine fitted to the Centurion was the Rolls-Royce Meteor. This was based on the Merlin Aero-engine modified for vehicle use and was first used operationally on the Cromwell Tank. In December 1942 Rolls-Royce came to an arrangement for Rover Ltd to take over the production of the Meteor whilst Rolls-Royce took over the development of jet engines; at the time Rover was leading the work on jet engines with Rolls-Royce in support. Rover took over full responsibility for the production of the Meteor, and its derivatives, in January 1944, and continued to manufacture the engines until 1964. The engine fitted to the A41 prototypes was the Meteor Mark 4 which generated 570bhp. This had been increased to 600bhp for the Mark 1. The Mark 2 saw the introduction of the Mark 4A which generated 650hp and the Mark 3 had an improved Mark 4B giving the same power output. The gearbox was the Merritt Brown Z51, a development of that fitted to the Comet tank, giving five forward and two reverse gears. An alternative gearbox, the Sinclair-Meadows Powerflow automatic gearbox, was fitted to Prototype No.5 which was designated the A41S. This gearbox had eight forward and two reverse gears but was not adopted.

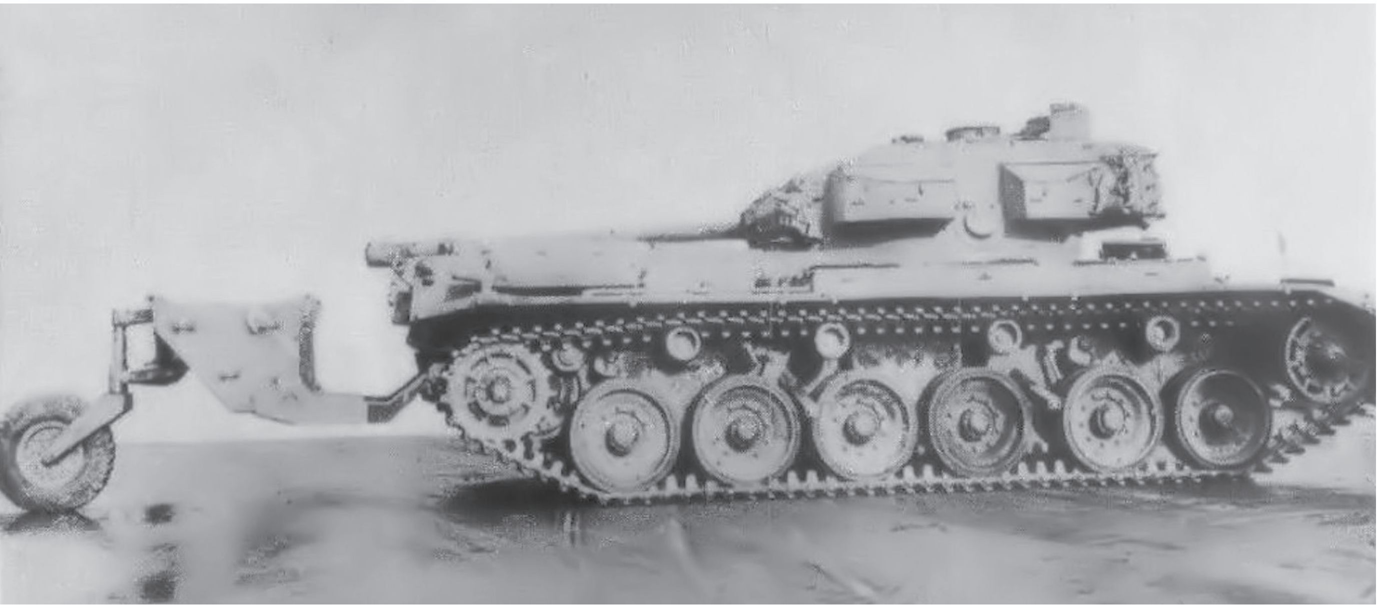
Although not fitted to the prototypes, consideration continued to be given to the provision of a hull-mounted machine gun with a report proposing solutions issued in 1945; however, none of the proposals was taken forward.

As a result of user testing of the prototypes a number of changes were requested and incorporated into the Mark 1. This had the same armament as prototypes 11–15 and went into limited production for troop trials and training. By August 1947, 100 Mark 1 vehicles had been manufactured of which 70 were delivered to the Field Army; by that time it was agreed that the remaining Mark 1s would be converted to the Mark 4 build standard. The conversions did not go ahead but these Mark 1s were used for other variants. The Mark 1 was soon followed by the Mark 2 which had thicker armour, increased from 127mm to 152mm, and a new design cast turret which incorporated a cupola with all-round vision for the commander. It also had the improved version of the Meteor engine. The Centurion Mark 2 was the first version to go into full production and entered service with the 5th Royal Tank Regiment in December 1946. By July 1948 244 Mark 2s had been delivered.

A key innovation introduced early to the Centurion was the use of electrical stabilization of the main weapon in both elevation and azimuth and this was first fielded on the Mark 3. The Department of Tank Design had first looked at gun stabilization systems in 1941 when a hydraulic elevation stabilization system of the type fitted to US Lee/Grant tanks was tested on a cruiser tank at Lulworth. This approach was not taken forward but in 1943 work started on an electromechanical system developed in cooperation with Metropolitan Vickers and first tested on a Centaur. That exercise gave confidence in the approach and led to the development of a system for Centurion. The equipment was installed in a development turret mounted on the prototype hull P2 and used in trials at Kirkcudbright in 1946. By October 1947 six modified Centurion Mark 2s were at Lulworth for user trials following which, in early 1948, the system was accepted for use on production vehicles. The Centurion was thus the first operational tank to have electromechanical stabilization for the main weapon in both azimuth and elevation, a system which provided a significant improvement in the probability of hitting a target when moving. The use of electrical weapon stabilization contributed to Centurion being a more survivable vehicle than contemporary NATO vehicles which had hydraulic stabilization systems.

As well as stabilization the Mark 3 also saw the introduction of the 20-pdr gun. Originally designated the QF3.3-Inch, it was 83.8mm in diameter and had a barrel length of 66.7 calibres. The 20-pdr design was based on that of the 17-pdr but exploited lessons from analysis of the German 88mm KWK43 weapon fitted to the King Tiger, and even though it was of slightly smaller calibre than the German 88mm it could penetrate armour nearly twice as thick. Key to the performance of the weapon was a new Armour Piercing Discarding Sabot (APDS) round. APDS rounds had been under development in the UK since 1941 and replaced the Armour Piercing Capped Ballistic Cap (APCBC) ammunition previously used. The APDS ammunition had a full-bore sabot around the amour piercing core which fell away once the round left the barrel. The overall round was lighter than a conventional round and so had a higher muzzle velocity. In flight, being of smaller diameter, there was less drag and therefore a lower velocity drop, resulting in better performance at longer ranges. The muzzle velocity was 1465m/s, the highest of any in-service tank gun at the time and, as well as good armour-piercing capability, the high velocity gave it a flatter trajectory which increased accuracy. This high accuracy was used to great effect in the Korean War. The ammunition was 618mm long and of larger diameter than the 17-pdr requiring the ammunition stowage to be revised with 65 rather than the original 74 rounds being carried. The Mark 3 was also fitted with a coaxial Browning machine gun in place of the original Besa. Work had started on the Mark 3 even before the Mark 2 had entered service, with a mock-up at Chertsey being completed for examination by the Army on 3 October 1946. By July 1948 29 Mark 3s had been delivered and in November 1948 the Mark 3 with the 20-pdr gun was adopted as the Army standard operational version to equip all tank regiments; apart from the 7th Royal Tank Regiment in Hong Kong which was to retain the Comet.

The Mark 3 first saw action in Korea where it was found to be much superior to the Soviet-built T34/85 tanks it came up against. Based on user feedback numerous minor changes were made to improve the ~Mark 3 with 250 being recorded by 1950, including changes to the loader's hatch and the deletion of the rear escape hatch.



Centurion Mark 3 with mono-trailer. (Crown Copyright MOD)

A limitation of the Mark 3 was its short range of only 62 miles. To address this issue an armoured trailer was developed to carry additional fuel. Designated FV3751 it had a single wheel at the rear, hence the designation 'Mono-Trailer'. It weighed 2 tons when full and was fitted with an under-armour jettison system. Trials were completed in 1952 and it was built by Joseph Sankey Ltd. It was also supplied to Sweden and Holland. In 1953 the design was modified to have provision for a support arm to be used when crossing combat bridges without a central running track. Despite the range benefits it was not liked by the user. The use of external fuel barrels mounted at the rear of the hull was also considered and in 1951 a range of trials were undertaken using prototype P10. These involved firing 20mm Hispano cannon and 0.50 Browning machine gun rounds, including tracer rounds into barrels filled with petrol. Although the barrels ignited, they usually fell off and, even when they remained in place, damage was generally limited to the road wheel rubber.

The Mark 4 was intended to be a close support tank with a 95mm Howitzer. A Mark 1 was modified to this configuration in 1947 but it did not enter production.

Development of the Mark 5 started in 1952 with Vickers-Armstrong working under the direction of the Fighting Vehicles Research and Development Establishment (FVRDE). It was of the same overall configuration as the Mark 3 but had a range of improvements including a 0.30in. Browning coaxial machine gun, revised loader's periscope and an upgraded gun and fire control system.[1] Later Mark 3 production vehicles saw the introduction of a fume extractor fitted to the 20-pdr gun. There had been a noticeable increase in fumes collecting in the turret with the introduction of the larger gun, and research into fume extractors had been under way since 1950. A fume extractor is a short cylinder around the barrel typically around halfway along its length. Holes in the barrel allow high-pressure gases to enter the fume extractor when the gun is fired; once the round exits the barrel, the high-pressure gas exits the fume extractor through holes that are angled towards the muzzle creating a forward flow of air that clears the barrel as the breach is opened. Following trials of a gun fitted with a fume extractor at Lulworth a report was issued in January 1957 recommending that it be fitted to all vehicles. As further improvements were developed for the

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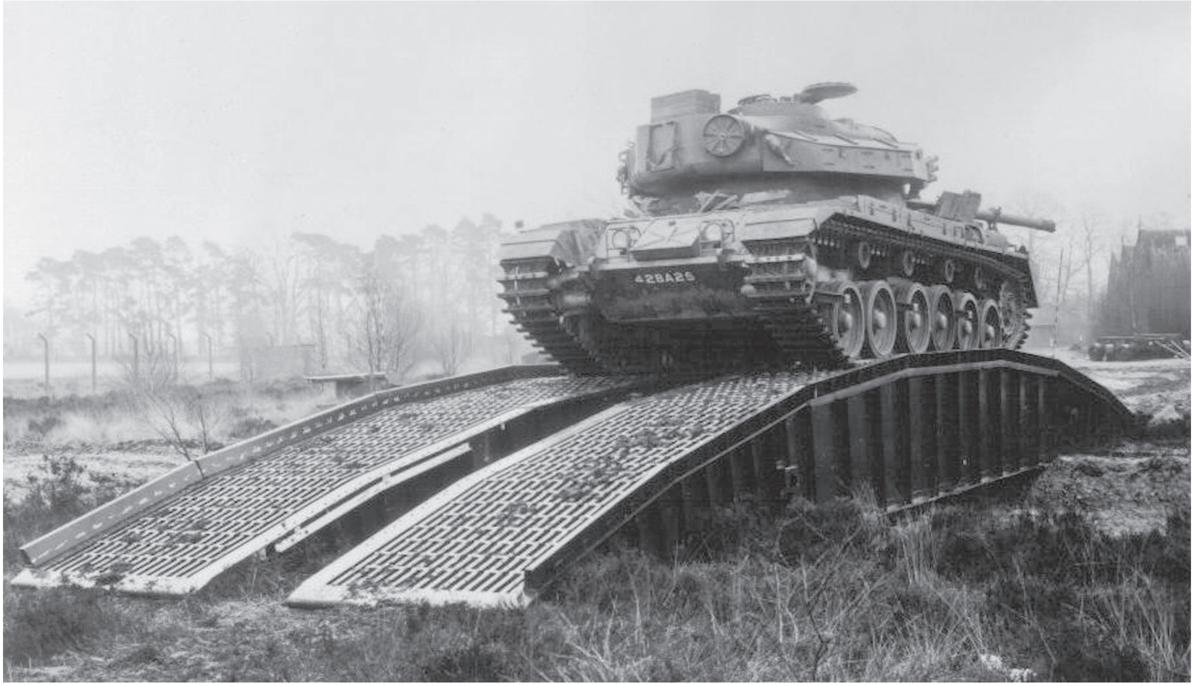
[1] The 'gun and fire control system' is the name given to the complete gun stabilization and aiming system on British tanks.



Centurion Mark 7 crossing a No.6 bridge. (Crown Copyright MOD)

Centurion, they were retrofitted to the Mark 5 with the updated version, which included the additional armour and 105mm gun, being referred to as the Mark 6.

Around 2,500 Mark 5s sold to overseas customers and most of these were manufactured on a production line set up at the Ministry of Supply factory at Farringdon near Preston. Sometimes called the 'Tank Arsenal', it was run by Leyland Motors.

The Mark 7 involved some significant design changes including the provision of a full turret turntable floor and increased ammunition stowage. It also had increased fuel capacity, up from 123 gallons to 228. A Centurion Mark 7 undertook hot weather trials in Libya in 1956. Moreover, desert trials were started on 'hardened' tracks that year which gave a longer track life.

Thicker armour was also subsequently introduced to the Mark 7 (designated the Mark 7/1) and this was likewise retrofitted to earlier Marks. The retrofit scheme involved an additional 51mm appliqué plate being welded to the upper hull glacis. This modification also required changes to the front track guard supports and the headlight harness. The main driver for this change was the fielding of the T54 tank by the Soviet Union which posed a more significant threat than the T34/85s that it replaced.

One of the most significant upgrades to the Centurion was the fitting of the 105mm L7 gun. Development of this gun began using a 20-pdr barrel bored out from 83.8mm to 105mm thus providing a gun that was of a larger calibre and with a greater expansion ratio of the propellant gases. The increase in calibre was matched by improvements to the APDS round it fired with the move from tungsten carbide rounds to new improved tungsten alloys. Work on the 105mm was undertaken in 1954 leading to successful firings of a re-bored barrel. However, initially development was not taken any further. Then in October 1956, during the Hungarian Revolution, a captured Russian T54A was driven through the gates of the British Embassy and the opportunity taken to examine the vehicle. It was assessed that the performance of the 20-pdr against the thick-sloped frontal armour of the T54 would be marginal and so work on the 105mm was restarted. Re-arming of Centurions with the new gun began in 1959. Trials in Germany indicated an armour defeat performance improvement of 25 per cent over the 20-pdr. A later development of its armour-piercing round, the L52 APDS, could penetrate 120mm of armour steel at 60 degrees at ranges up to 1,830m. As well as the Centurion the L7 was adopted by other nations for their Main Battle Tanks, including the US (M60), Germany (Leopard 1), Sweden (S-Tank) and Japan (Type 74) with around 35,000 different tanks of different designs mounting the weapon. On the Centurion the effectiveness of the gun was supported by the use of a Ranging Machine Gun (RMG). Research and development of a ranging machine-gun solution, as an alternative to bulky and expensive optical rangefinders, had been ongoing at Chertsey since the early 1950s and trials demonstrated that its use significantly improved the first-round probability of hit, especially when firing High Explosive Squash Head (HESH) rounds. To enhance the effectiveness of the RMG a new gunner's sight was developed, the AFV Periscope No.27 Mark 1.

When available, the 105mm gun was retrofitted to existing vehicles as well as new-build vehicles. It was introduced during the production of the Mark 7 and around 200 conversion kits were manufactured for converting the early Mark 7s, the converted version being designated the Mark 9. Other earlier Marks were also up-gunned. As well as replacing the barrel, the conversion to the 105mm gun required new buffer lugs, ammunition racks and clips, gun depression rail, cartridge case deflector, sight scales and barrel cleaning equipment. In addition, modifications to the gun crutch were required.

Later Marks of Centurion had a white light/Near Infrared (NIR) Search Light and NIR headlights, which were introduced from 1962 onwards. Another innovation introduced on the Mark 8 was a contra-rotating cupola which automatically maintained the commander's line of sight regardless of the gunner traversing the turret. The Mark 8 also had a new resilient mantlet, which was better for mounting the larger 105mm gun, and a new rack and pinion elevating gear. Design work on the new mantlet had been going on for several years with full ballistic trials of the proposed design being undertaken in 1957.

Further minor improvements were developed and assessed even when the Chieftain tank was starting to enter service, for example in March 1966 a report was issued on a system trialled on Centurion and Saladin for providing pressurized air to crew when wearing respirators in order to reduce their breathing load. In November 1965 a report on installing Swingfire missiles on Centurions was issued. The British Aircraft Corporation (BAC) undertook a trial installation as a private venture activity and a vehicle was displayed at the 1971 British Military Vehicles exhibition. This had two ready-to-fire missiles mounted either side of the turret and additional missiles stored at the rear of the turret. The periscopes for target acquisition and missile guidance were linked to the stabilization system to enable firing on the move.

The designation of the different versions of Centurion is somewhat complex, due to the range of different build standards applied to new and updated vehicles, the main versions being:

Mark 1 (A41*): Initial production model
Mark 2 (A41A): Modified turret design, increased armour and an improved engine
Mark 3: Initial standardized version with stabilized 20-pdr gun; most later upgraded to Mark 5 standard
Mark 4 (A41T): 95mm howitzer close support tank – not put into production
Mark 5: Upgraded gun and fire control system, fitting a .30in. Browning machine gun in place of the 7.62 Besa and other minor changes
Mark 5/1: Mark 5 with the additional armour welded to glacis
Mark 5/2: Mark 5 up-gunned with the L7 105mm gun

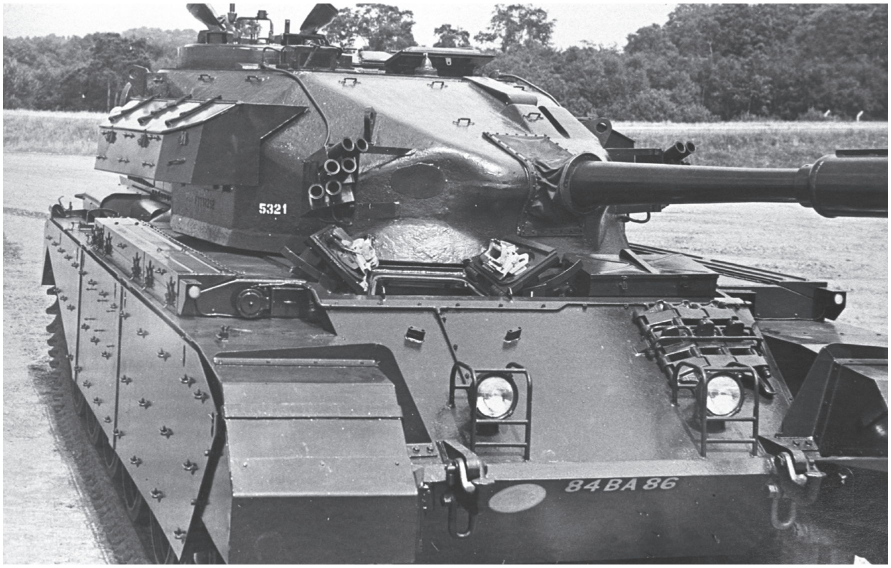
NEXT PAGES
Mark 13 Centurion, a preserved vehicle from the Norfolk Tank Museum. (Author's Collection)

DUCHESS

09 BB 33
ATHENA
Centurion Mk 13

Mark 6: Mark 5 with both the additional armour and 105mm gun
Mark 6/1: Mark 6 with infrared (IR) searchlight and turret stowage bins
Mark 6/2: Mark 6 with ranging machine gun
Mark 7 (FV4007): Improved design with turret turntable and increased fuel capacity
Mark 7/1 (FV4012): Mark 7 with additional armour
Mark 7/2: Mark 7 with 105mm gun
Mark 8: New turret mantlet which improved the gun mounting, new elevation gear mechanism and a contra-rotating cupola
Mark 8/1: Mark 8 with additional armour
Mark 8/2: Mark 8 retrofitted with 105mm gun
Mark 9 (FV4015): Mark 7 with 105mm gun and additional armour
Mark 9/1: Mark 9 with night-fighting equipment
Mark 9/2: Mark 9 with ranging machine gun
Mark 10 (FV4017): The final new-build version which was in production between 1959 and 1960. It was a Mark 8 fitted with the 105mm gun, stowage for 70 rounds, improved gun stabilization system and improved armour
Mark 10/1: Mark 10 with night-fighting equipment
Mark 10/2: Mark 10 with ranging machine gun

Centurion tanks at the Long Valley test site. (Crown Copyright MOD)



Centurion Mark X with a prototype cleft turret. (The Tank Museum, Bovington)

Mark 11: Mark 6 with night-fighting equipment, ranging machine gun and stowage basket on the turret rear
Mark 12: Mark 9 with ranging machine gun and turret basket
Mark 13: Mark 10 with ranging machine gun, night-fighting equipment and the L7A2 105mm gun

The production of new-build vehicles was undertaken as follows:

Mark 1: Woolwich, ROF Leeds and ROF Nottingham
Mark 2, 3 and 5: ROF Leeds, ROF Dalmuir, Vickers-Armstrong, and the Farringdon 'Tank Arsenal' near Preston
Mark 7 and 8: ROF Leeds and the Farringdon
Mark 10: ROF Leeds

At least one standard Centurion hull was fitted with a cleft turret of the type fitted to FV4202. The turret equipment was to Mark 9/2 standard with a contra-rotating cupola and ranging machine gun. It is sometimes referred to as the Mark X.

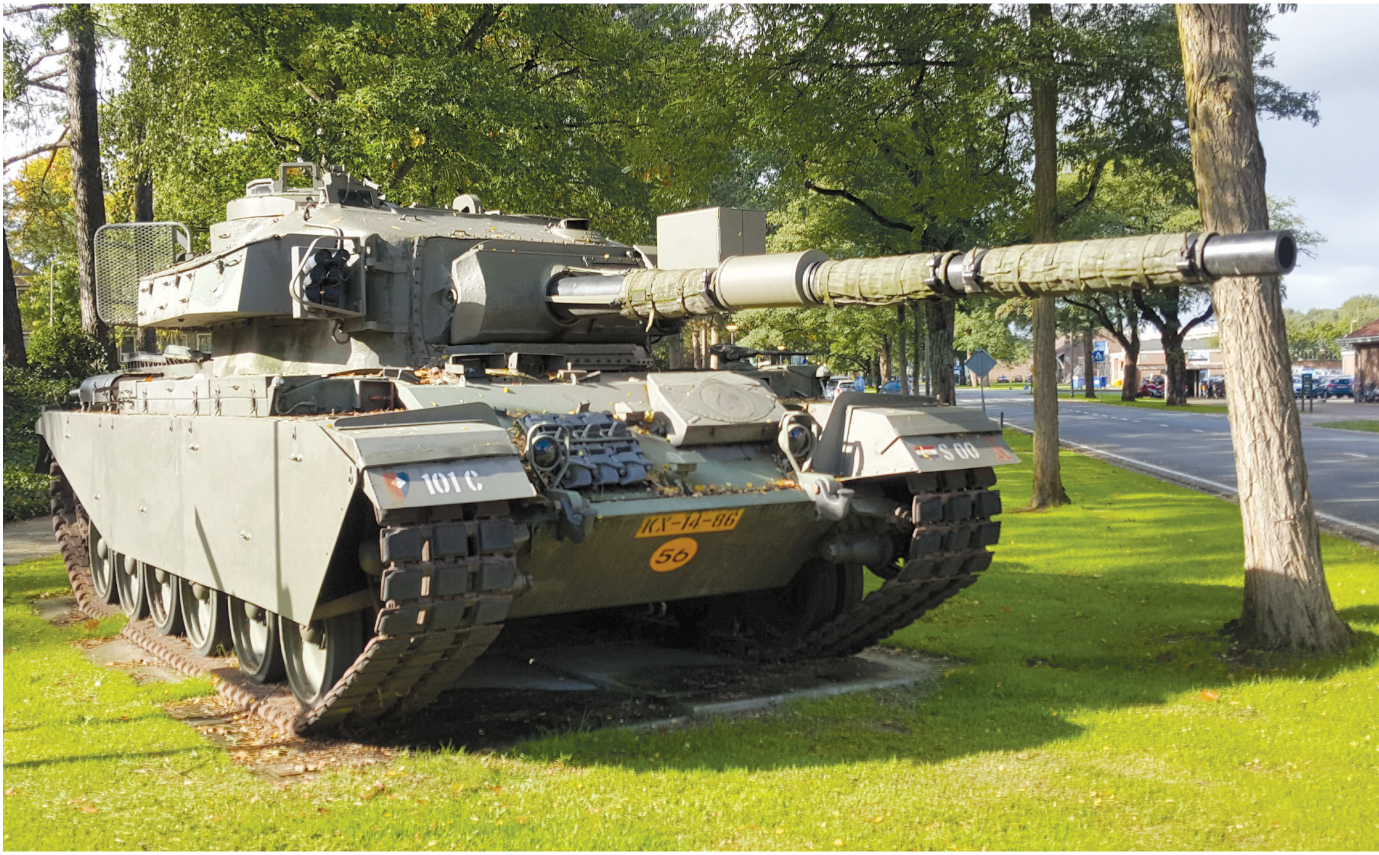
In 1967 a study was undertaken into installing the L60 engine, as used in Chieftain, in Centurion. This would have given commonality of spares and fuel type between the Chieftain and Centurion vehicles and variants still in service but, with ongoing reliability issues with the L60, the idea was not pursued.

CENTURION IN SERVICE USE

The Centurion was recognized as one of the world's best tanks of its time and has been in service in Australia, Canada, Denmark, Egypt, India, Iraq, Israel, Jordan, Kuwait, Lebanon, the Netherlands, New Zealand, South Africa, Sweden and Switzerland.

Although too late to see action in World War II, Centurion was used to good effect in a number of conflicts. As discussed, it first saw action in Korea where, as well as the accurate weapon, the robustness of Centurion was a key factor in its success, especially in light of the widespread use of artillery by the opposing forces. The first vehicles to arrive were three squadrons of Mark 3s of the 8th Kings Royal Irish Hussars which landed at Pusan on 14 November 1950 and saw particularly fierce fighting at the battle of Imjin River in April 1951 and again in the same area taking part in Operation *Commando*. The Hussars were relieved by the 5th Royal Inniskilling Dragoon Guards in

Late Mark Centurion as used by the Dutch Army. (Author's Collection)



December 1951. By this time the warfare was largely static but the tanks continued to provide excellent service, often providing fire support once they had climbed seemingly impossible slopes to dominant fire positions. A number of vehicles were fitted with US searchlights to counter Chinese attacks and patrols at night, often with one vehicle illuminating the targets and another engaging them. The effectiveness of the Centurions meant they were often the target of Chinese artillery and mortar attacks. Rocket-propelled anti-tank weapons were another threat and one vehicle of the Royal Inniskilling Dragoons was repaired, following a hit to the hull glacis, by having a track pin welded in the hole. The 1st Royal Tank Regiment took over in December 1952. Both the Dragoons and 1st Royal Tank Regiment provided invaluable support in fighting around Hook Hill in November 1952 and May 1953. During the May 1953 battle supporting the defences against mass attacks by the Chinese, C Squadron of 1st Royal Tank Regiment fired 504 rounds of 20-pdr ammunition and 22,500 rounds of machine-gun ammunition. The tanks suffered an average of five direct hits from shells and mortars without loss. The excellent mobility was also of note in the steep rocky terrain of Korea, and when vehicles sustained damage to the turret it was common to remove the turret and use the vehicles as ‘tugs’ to transport stores to remote inaccessible locations. In addition to the challenges of terrain and enemy action, the vehicles also had to cope with the Korean winter with temperatures as low as -26°C recorded in the winter of 1950/51. At the Royal Armoured Corps conference held in November 1957, Major Nelson of the 8th Hussars reported on its performance,

> We gave the tanks a thorough bashing and before I left the average mileage was 1,200. They have shown themselves to be extremely good cross-country vehicles. There are very few steep hills which they could not get up. They would cross paddy unless it was extremely soft and bottomless. Centurions would sink less deeply in paddy than Cromwells’ or Carriers. The 20pr guns were so accurate that you can, what we call ‘Post letters into pill boxes’.

His only regret was the fact that they had had little opportunity to take on enemy tanks. The success of the Centurion in Korea was one of the main factors that resulted in many overseas sales.

Centurion gun tanks also saw action with UK forces in Egypt during the Suez crisis where, with vehicles fitted with deep wading kit, they were used to support the Royal Marine Commandos during the initial landings on 6 November 1956.

Centurion was also used operationally by the Indian Army during the Indo-Pakistan war of 1965. One infamous engagement was the battle of Asal Uttar on 10 September 1965 where, in the face of the invading Pakistani forces, Maj. Gen. Gurbaksh Singh of the Indian Army ordered his division to fall back and assume a horseshoe-shaped defensive position with Asal Uttar as its focal point. The Indian armoured force consisting of 45 Centurion tanks and around 45 Sherman tanks and 45 AMX 13 faced a force of 176 US-built Patton tanks and 45 M24 Chaffee light tanks. In the night, the Indian troops flooded the sugar cane field which impeded the mobility of the attacking Pakistani tanks and it is reported that in the ensuing battle 99 Pakistani tanks were destroyed or captured for the loss of only ten Indian tanks. Meanwhile, in the Sialkot region, the Indian Army launched a counter-attack which resulted in the largest tank battle since World War II. The Indian troops were initially concerned about the potential superiority of the US-supplied M48 Pattons; however, the Indian crews employed the 'three round battle range technique' developed by Col. Eric Offord when he was the commandant of the Lulworth Gunnery School. This was used for target ranges below 1,000 yards (914m) and involved firing three rounds in quick succession with aim points at 800 yards, 1,000 yards and finally 600 yards; this usually resulted in two or three hits within 20 seconds – well before the gunner of the more complex Patton could fire his first round. As well as being able to rapidly destroy the enemy armour the Centurion proved once again to be robust against attack with one Mark 7 tank of the 3rd Cavalry Regiment continuing to be operational after 15 hits.

The Israelis also had much success using Centurions with various upgrades, and considered it far more survivable than the later US M60s in service at the same time. Of note were the actions involving Centurions in the Sinai Peninsula in the 1967 Six Day War and in the Golan Heights in 1973. One notable incident during the Six Day War was the battle of the Mitla Pass; after the war the brigade commander, Col. Iska Shadni addressed the question of how they were able to destroy 157 enemy tanks for almost no losses; he outlined training, support from the air force and the Centurion tank which he said proved to be far superior to the T54 and T55 tanks equipping the opposing Egyptians.

Centurion was the main Israeli tank used in the Golan Heights in 1973 because its running gear was much better suited to the terrain than the M48 and M60 tanks also in service. Initially around 177 Centurions faced an attacking Syrian division of 540 tanks with two further Syrian divisions in reserve. By this time the Centurion had been up-gunned to the 105mm weapon and this proved more than adequate for dealing with the Syrian T62s. Again the robustness of Centurion was demonstrated; analysis after the conflict concluded that on average each vehicle received three hits by various weapons but less than 10 per cent of the fleet was damaged beyond repair.

The South African Army updated its Mark 2 and 3 Centurion tanks with the 105mm L7 gun, a new engine, updated sights and enhanced protection, calling the resulting vehicle Olifant. This entered service in 1978 and was used with much success against T34 and T55 tanks in Angola, although it had less success against Cuban T62 tanks.

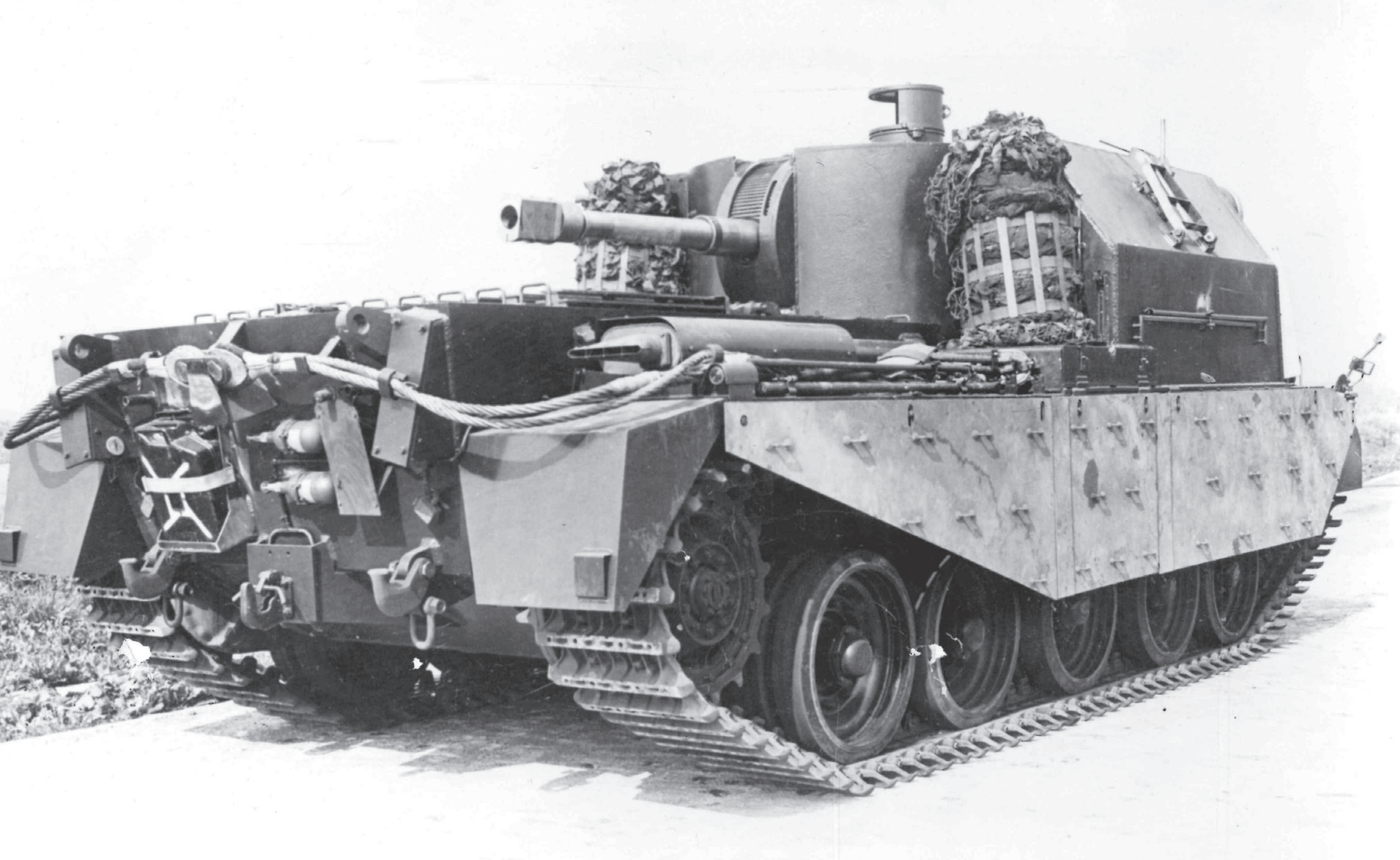
The Centurion was a key asset for the Australian units in action in Vietnam where 58 vehicles were fielded between February 1968 and August 1971. Its presence on the battlefield provided effective support to infantry in offensive and defensive actions; this was despite being operated in very different terrain and scenarios than those for which it was designed. The response of infantry to the presence of supporting Centurion tanks is given in the C Squadron 1 Armoured Regiment narrative in Commander's Diary describing the battle of Long Dien (22 August 1968) where Australian infantry drove threat forces out of the town supported by four Centurion tanks. 'The infantry moved astride the roads and indicated targets to the tanks which moved forward to engage them. The infantry were overjoyed.'

The After Action Report of Operation *Tong and Hammer* describes the battle of Binh Ba, 6–8 June 1969, stating 'Tank support was outstanding and there is no doubt their activities were a battle-winning factor. They moved with infantry, covered the movement close up to houses assisting infantry to get into the houses to deal with the enemy inside bunkers and tunnels.' An assessment of the Centurion when supporting operations in urban areas in Vietnam states:

> The enemy's light anti-armour weapons – the RPG 2 and RPG 7 [rocket-propelled grenades] – were unable to inflict significant damage on the Centurion tank, particularly when it was given infantry protection.

> Only at the battle of Binh Ba were tanks put out of action and then only under very heavy RPG fire leading to numerous hits and when the tanks were being 'misemployed' without the protection of dismounted infantry to suppress the fire of the enemy RPG gunners.

One Australian Army Centurion Mark 3 has a unique claim to fame, vehicle No.169041. Built in 1951 it was delivered to the Australian Commonwealth Government in 1952. On 15 October 1953 it was used in a nuclear weapon experiment at Emu Field when it was placed less than 500m from a 9.1kt weapon blast. The blast moved the vehicle nearly 2m, removed antennae, damaged sights and lights, incinerated the mantlet cover and blew off the skirt plates – which landed some 200m away. After the trial the vehicle was driven away and the damage repaired. Nicknamed 'The Atomic Tank' it later saw action in Vietnam where in May 1969 it was hit with an RPG. There were some injuries to members of the turret crew, but no fatalities, and the vehicle remained battle worthy with no critical components damaged. The tank remained operational until May 1992 and is now at the Robertson Barracks in Australia; the only vehicle to survive an attack by both nuclear and conventional weapons.

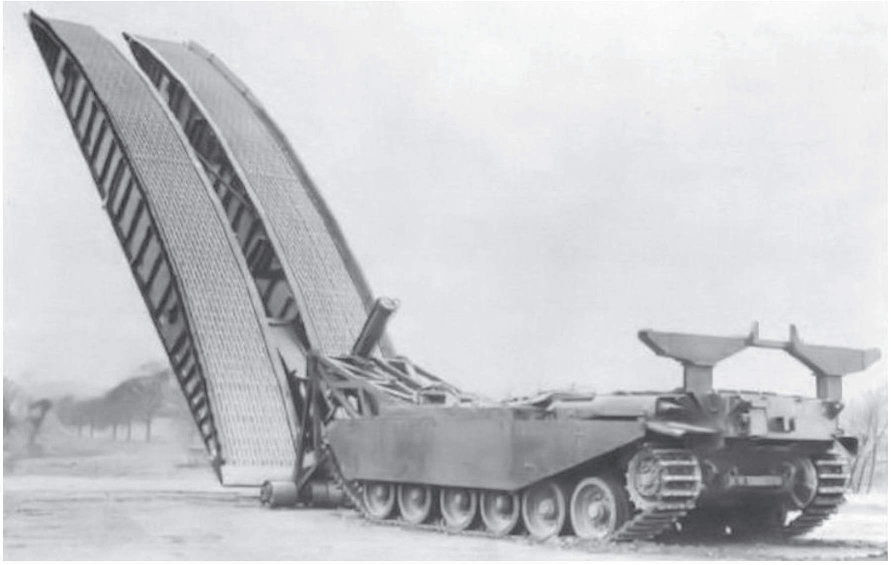


FV3802, prototype 25pdr self-propelled gun based on a shortened Centurion hull with five wheel stations. (The Tank Museum, Bovington)

CENTURION VARIANTS

In addition to the gun tanks a wide range of variants were developed either based on the gun tank, or using the hull or major sub-systems. Some proposed variants were only the subject of initial concept work or only reached the design or prototype stage. The following is a list of proposed and fielded vehicles that were based on the Centurion hull or major assemblies:

FV3801: Gun tractor
FV3802: 25-pdr self-propelled (SP) gun
FV3803: Command post vehicle
FV3804: Ammunition vehicle
FV3805: 5.5in. SP guns (two prototypes)
FV3806: 7.2in. SP gun Centurion components (proposal only)
FV3807: 120mm SP anti-tank gun (proposal only)
FV3808: SP gun (proposal only)
FV3809: 155mm SP gun (proposal only)
FV4001: Centurion mine clearer
FV4002: Centurion Mk 5 bridge layer
FV4003: Centurion Mk 5 Armoured Vehicle Royal Engineers (AVRE) 165
FV4004: Conway tank destroyer with 120mm gun
FV4005: Heavy self-propelled anti-tank gun, 180mm
FV4006: Centurion ARV Mk 2
FV4007: Centurion Mk 1, 2, 3, 4, 7
FV4008: Centurion Duplex Drive (DD)
FV4010: Tank Destroyer, Centurion-based Medium Orange William or Malkara missile launcher
FV4011: Centurion Mk 5
FV4012: Centurion Mk 7/1, 7/2, 8, 8/1, 8/2
FV4013: Centurion Mk 1 Armoured Recovery Vehicle (ARV)
FV4015: Centurion Mk 9, 9/1, 9/2 10
FV4016: Centurion Ark bridge layer
FV4017: Centurion Mk 10, 11, 12, 13
FV4018: Centurion Beach Armoured Recovery Vehicle (BARV)
FV4019: Gun tank modified to carry flamethrower, development work only (hence the number was re-used)



FV4002 Centurion Mark 5 Bridge Layer deploying a No.6 bridge. (Crown Copyright MOD)

FV4019: Centurion Mk 5 with Bulldozer blade from FV4003
FV4203: Centurion AVRE – with 105mm gun – modified gun tank

The FV4002, Centurion Mark 5 bridge layer, was based on the Mark 5 chassis and was designed to carry and launch the Number 6 Class 80 single-span bridge that could be used to span gaps of up to 13.72m.[2] Work had started on bridge-laying equipment in 1946 in support of the proposed A45-based FV208 bridge layer. In the absence of an A45 hull, a mock-up of the launching mechanism was mounted on a Centurion. This work was exploited for the FV4002, the first prototype of which was delivered to the Military Engineering Experimental Establishment (MEXE) at Christchurch in 1953.

A related gap-crossing vehicle was the FV4016 Centurion Ark which was very similar in layout to Arks based on Churchill and Sherman hulls that were built during World War II. The Ark had a trackway across the hull with hydraulically operated fold-out ramps at either end. When used operationally the Ark could be driven into a ditch or up against a sea wall and the ramps folded out to form a Class 80 bridge with a useable span of 75 feet. Designed by FVRDE, the Ark was based on the

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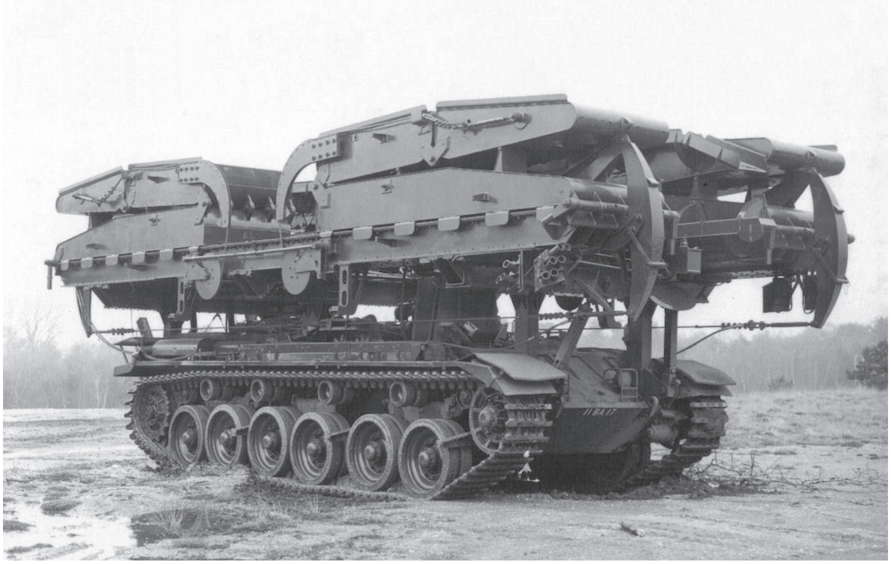
[2] All vehicles have a Bridge Classification or 'Class' which defines what bridges it can cross. The classification is related to the weight and running gear configuration of the vehicle which together determine the loading the vehicle places on the bridge.

Mark 5 hull with a plate covering the turret ring and it was formally accepted for service in 1959.

The FV4003, Centurion Mark 5 Armoured Vehicle Royal Engineers (AVRE), was based on the Mark 5 Gun Tank and mounted a 165mm L9A1 demolition charge projector. It was also fitted with a dozer blade and fascine launcher and could tow a sledge or armoured trailer which could be fitted with the Giant Viper mine clearance system. Although development started in 1950 it did not enter production until 1963. The Mark 5 AVRE was used in action by the British Army as late as 1991 when 12 were deployed with the 32nd Armoured Engineer Regiment to support Operation *Granby* – the UK operations to liberate Kuwait.

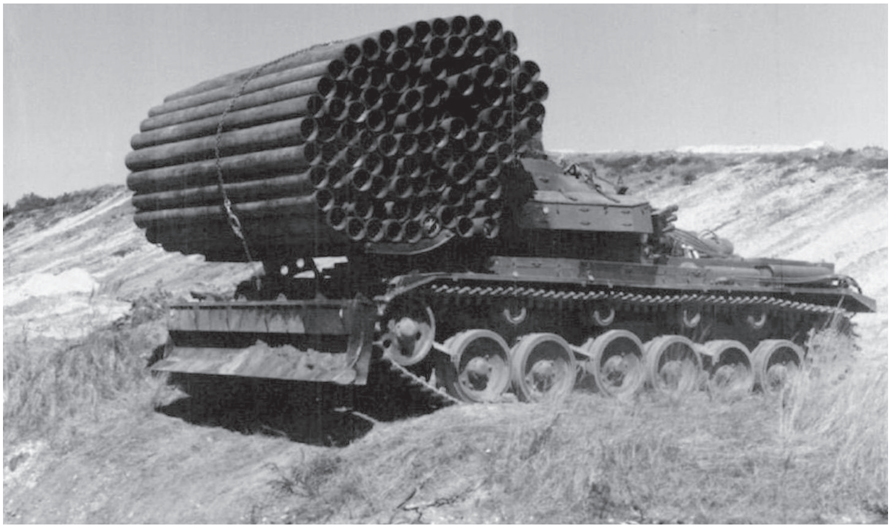
The Royal Engineers did take over some Centurion gun tanks that had been previously used by the Royal Artillery for forward observation officers but replaced by FV432s in that role. These were used to supplement the FV4003 AVREs and were only used to fire HESH rounds. Referred to as AVRE 105s, they were also equipped with mountings points for a mine plough and could tow either the Giant Viper mine clearance system or an AVRE trailer.

In addition to dedicated Royal Engineer Vehicles a number of Mark 5s were modified with mounting kits for the AVRE dozer blade. These were fielded with one vehicle in each operational squadron. The main intended function of these vehicles was to prepare hull-down defensive positions for gun tanks. This variant was also designated FV4019.

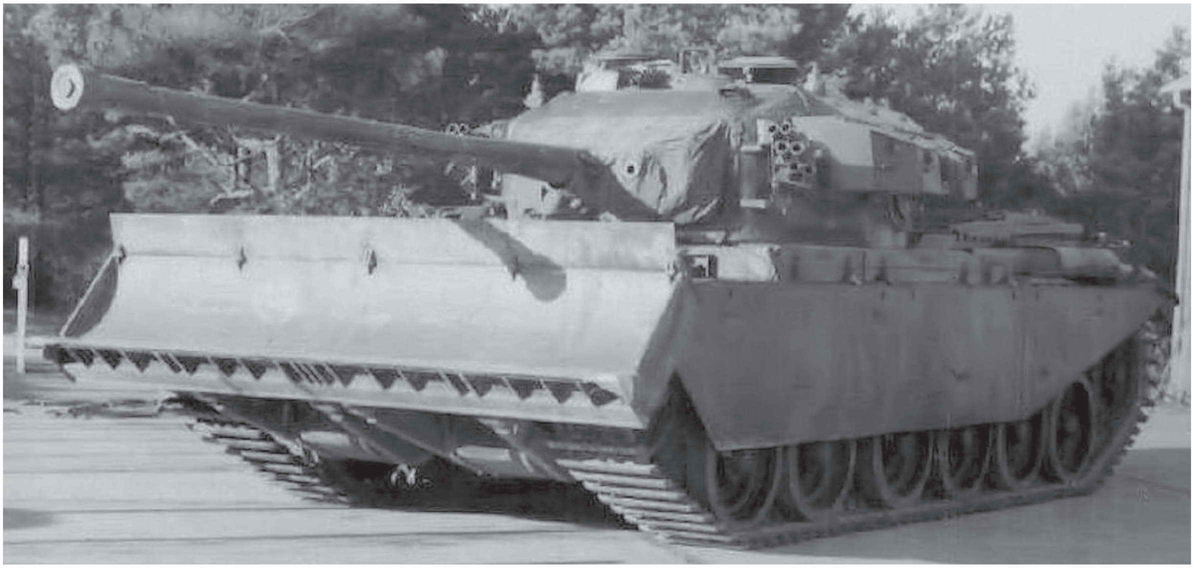


FV4016 Centurion Ark in travelling configuration. (Crown Copyright MOD)

RIGHT
Centurion AVRE with fascine and dozer blade. (Crown Copyright MOD)



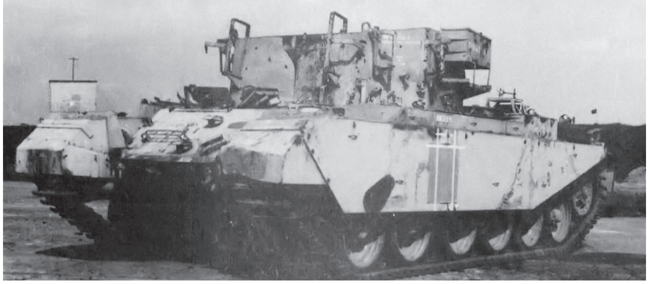
BELOW
Centurion Mark 5 with appliqué dozer blade. (Crown Copyright MOD)



The designation FV4019 had previously been allocated for Centurion tanks fitted with the Crocodile flame-throwing equipment. The proposal to bring Crocodile trailers and flame projectors out of store and fit them to Centurions was made following the cancellation of FV201 which was designed to be able to be converted to a flame thrower configuration when required. In 1952 a vehicle was fitted out with the equipment and plans to start training crews drawn up but the proposal was not taken forward and the formal British Army requirement for flame-throwing tanks was finally dropped in 1954.

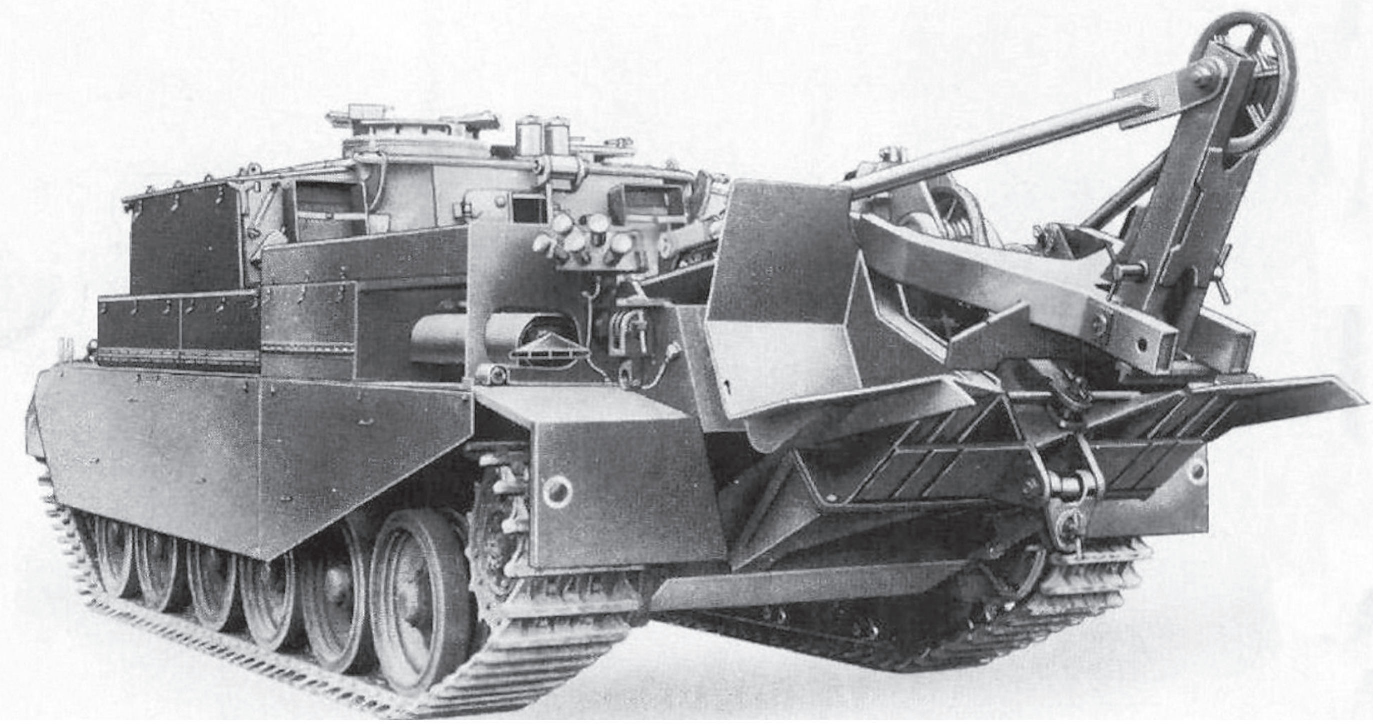
The FV4006 and FV4013 were Armoured Recovery Vehicles. These were developed to meet the requirement for a heavier recovery vehicle to support the Centurion when it entered service. Initially some obsolete Mark 2 gun tanks were converted for use as recovery tugs by local army workshops. The first purpose-built recovery vehicle, Centurion ARV Mark 1, was based on the same configuration as the Churchill ARV Mark 2 with an armoured box replacing the turret. A prototype was built at the Royal Electrical and Mechanical Engineers (REME) 13th Command Workshops at Aldershot and was fitted with an 18-ton winch powered by a six-cylinder Bedford truck engine. The recovery rope exited the superstructure through an aperture at the rear and then passed over the engine decks and through a pair of rollers mounted at the rear of the hull. A hull-width earth anchor was attached to the hull rear. By the end of 1951, 11 examples had been constructed, of which eight were sent to Korea and two to the British Army of the Rhine (BAOR). Eventually 170 Centurions were converted to Mark 1 ARVs with ongoing improvements progressively implemented. It has been suggested that some were fitted with a dummy gun.

Meanwhile Chertsey started design work on an ‘official’ recovery variant, the ARV Mark 2, which was designated FV4006. Following design work a prototype was built by Garner Motors of Acton which was completed in 1952. On this vehicle the turret was replaced by a fixed superstructure and the vehicle fitted with an electric winch rated at 30 tons. The superstructure was much longer and wider but lower than that on the Mark 1. Power was provided by a generator driven by a 160hp Rolls-Royce B80 engine. An earth anchor, which was bigger than that on the Mark 1, was fitted to the rear of the vehicle and a 10-ton rated jib could be attached to the front for lifting engines and other equipment. Large stowage bins were provided along the sides of the vehicle behind the superstructure and hence the stowage capacity for special tools and equipment was much greater than the Mark 1. Accepted for service in 1956, 345 were constructed at ROF Woolwich and Vickers-Armstrong, most based on conversions of obsolete Mark 2 gun tanks. Although much better than the Mark 1 ARV, the Mark 2 still had cramped crew conditions and a Mark 3 (FV4013), with a more spacious forward superstructure, was proposed but never proceeded beyond the design study stage.



A well-used Armoured Recovery Vehicle Mark 1 before its final use as a target vehicle for weapon trials at Shoeburyness. (Crown Copyright MOD)

ABOVE
FV4006 Centurion Armoured Recovery Vehicle crossing a No.6 bridge. (Crown Copyright MOD)



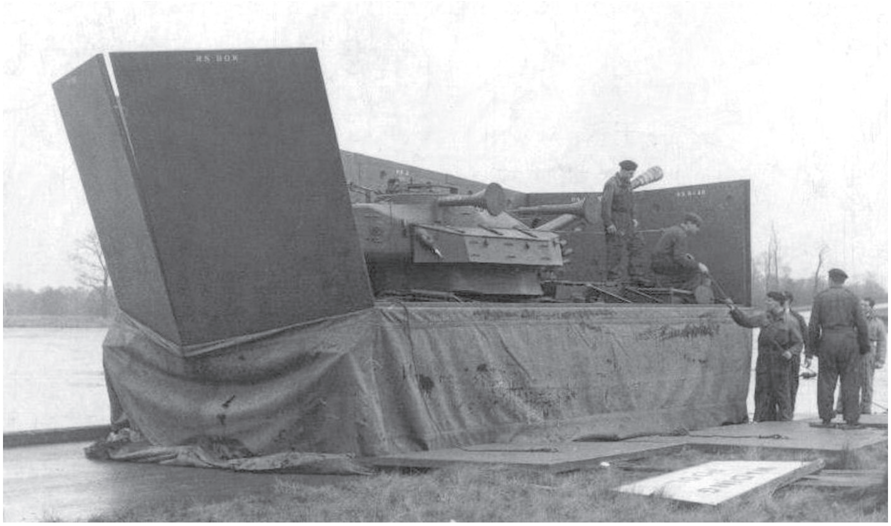
RIGHT
Centurion ARV Mark 2 with Jib in Working Configuration (rear view). Diagram from the user handbook. (Crown Copyright MOD)

Consideration was given to a Forward Repair Vehicle based on the Centurion ARV to support the UK/German Future Main Battle Tank (described in a later section) when it entered service. It would have had the winch removed and a 25-tonne crane added, along with a rack on the rear decks for carrying a power pack.

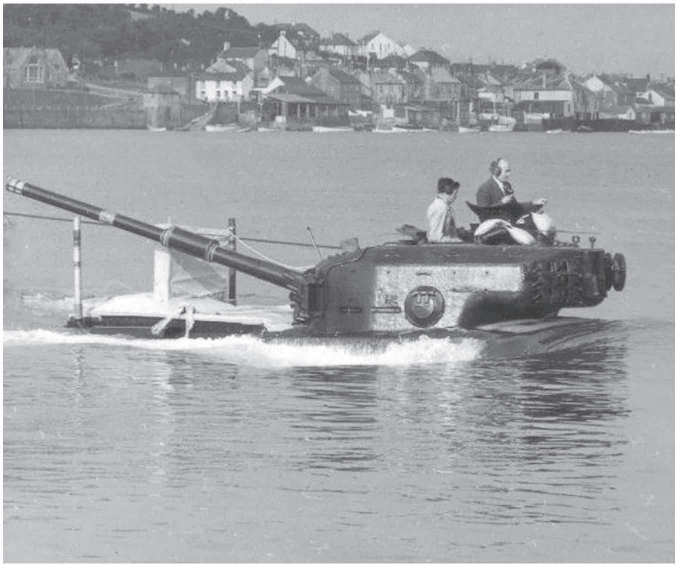
The FV4008 was the designation for an amphibious version of Centurion to provide a capability similar to the World War II 'DD' tanks which used a bellows-like flotation screen. The provision of a flotation system for Centurion was much more challenging than for the Sherman and the Valentine DD tanks. In addition to the significant increase in weight, there were issues due to the longer main gun and the lower silhouette. The silhouette was an issue, as for a DD scheme the canvas screen needed to be designed to fold into the space between the top of the track guards and the swept volume of the gun when depressed. Other challenges in developing a practical system, included the need for it to be compact so vehicles could fit in the Tank Landing Ships, the need to stow the flotation equipment on the vehicle when not in use and for it to be quick and easy to deploy and remove. A range of options for an amphibious capability was initially considered, including:

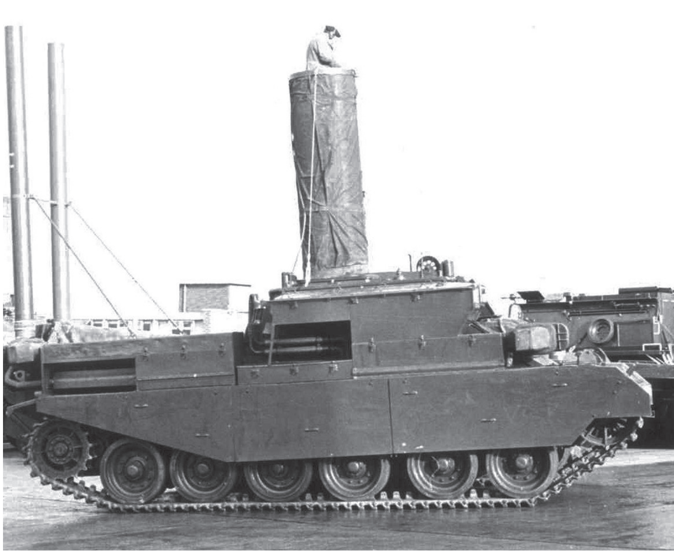
- an improved DD screen with better support mechanism;
- a flotation screen constructed from lightweight rigid panels;
- a sealed vehicle that could be towed along the sea/river bed;
- a sealed vehicle with breathing snorkel;
- a short flotation screen with inflatable rim; and panier floats.

Scale models of the schemes were built and tested in the Chertsey wading pit to assess the feasibility. Prototype versions of screen and inflatable rim



FV4008. The preferred design with rigid panels and canvas cover showing the panels being erected before the canvas cover being hoisted into place. (Crown Copyright MOD)





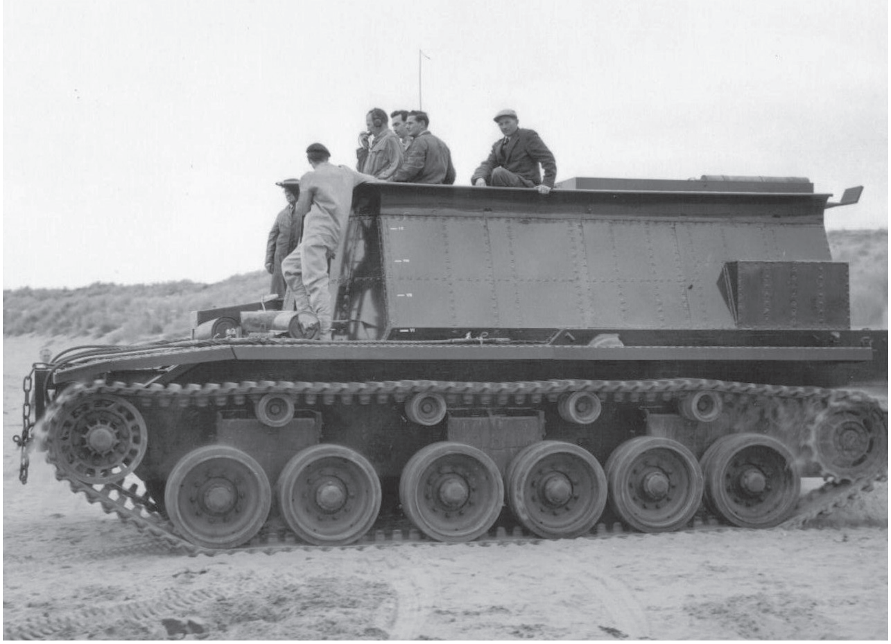
ABOVE
Centurion with prototype deep wading kit undertaking trials. (Crown Copyright MOD)

ABOVE RIGHT
Centurion ARV with snorkelling kit showing the conning tower for the vehicle commander and two exhaust extensions prepared for trials. (Crown Copyright MOD)

systems were built and these were also tested in the wading pit. The solution eventually selected was a 'boat' system similar in appearance to the World War II DD system consisting of a flotation screen around the vehicle and propellers for population. To cope with the higher vehicle weight, instead of a canvas screen, a system of rigid panels was used for strength, over which a fabric cover was fixed to make the system waterproof. The system was fully developed and tested, including being launched at sea from Tank Landing Craft, but was never fielded.

In addition to this full 'swimming kit', deep wading kits were also developed for Centurions and a demonstration of a Centurion with a 'snorkelling kit' was carried out by BAOR in 1965. Also in 1965 studies into underwater crossing of water obstacles were carried out. A snorkelling kit was also developed for the Centurion ARV.

The FV4018 was the Centurion BARV – Beach Armoured Recovery Vehicle. There was a requirement to replace the Sherman BARV which could no longer cope with the heavier vehicles entering service. An initial concept for a Centurion BARV was demonstrated by the REME Fording Trials Branch, who built a mild steel superstructure, based on the shape of that fitted to the Sherman BARV, on an old Centurion 'tug' tank. This was sent to the Amphibious Trials and Training Unit at Instow in Devon in 1958 for trials and subsequently used as the basis for the design of a fully armoured version by FVRDE. ROF Leeds built 12 vehicles using Mark 1, 2 and 3 hulls and these entered service in 1960. The vehicles



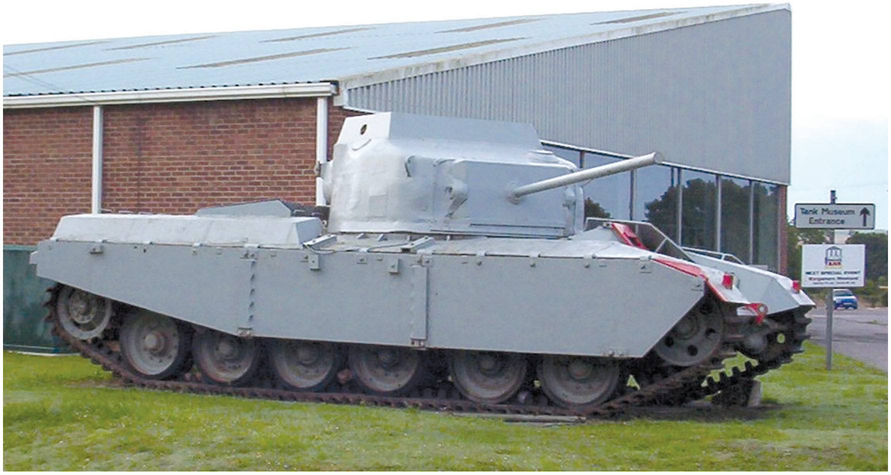
FV4018 Beach Armoured Recovery Vehicle. (Crown Copyright MOD)

were capable of wading to a maximum depth of over 3m without preparation. In 1982 two BARVs were sent to the Falklands as part of the UK task force.

Two other variants of the Centurion for which prototypes were built but which never went into production were the FV4004 Conway and the FV4005 183mm SP gun; these are discussed in a later chapter.

By 1953 a programme had started for a family of self-propelled guns and supporting command vehicles based on Centurion automotives and running gear. Previously priority had been given to the development of a lighter FV305 25-pdr self-propelled gun as a replacement for the World War II Sexton SP gun. However, when this was cancelled, effort was then focused on what was intended to be the FV3800 series. This was a proposed family of vehicles consisting of:

FV3801: Gun tractor
FV3802: 25-pdr SP gun
FV3803: Command post vehicle
FV3804: Ammunition vehicle
FV3805: 5.5in. SP gun
FV3806: 7.2in. SP gun
FV3807: 120mm SP anti-tank gun



Centurion moving target tank on display outside the Tank Museum, Bovington. (Author's Collection)

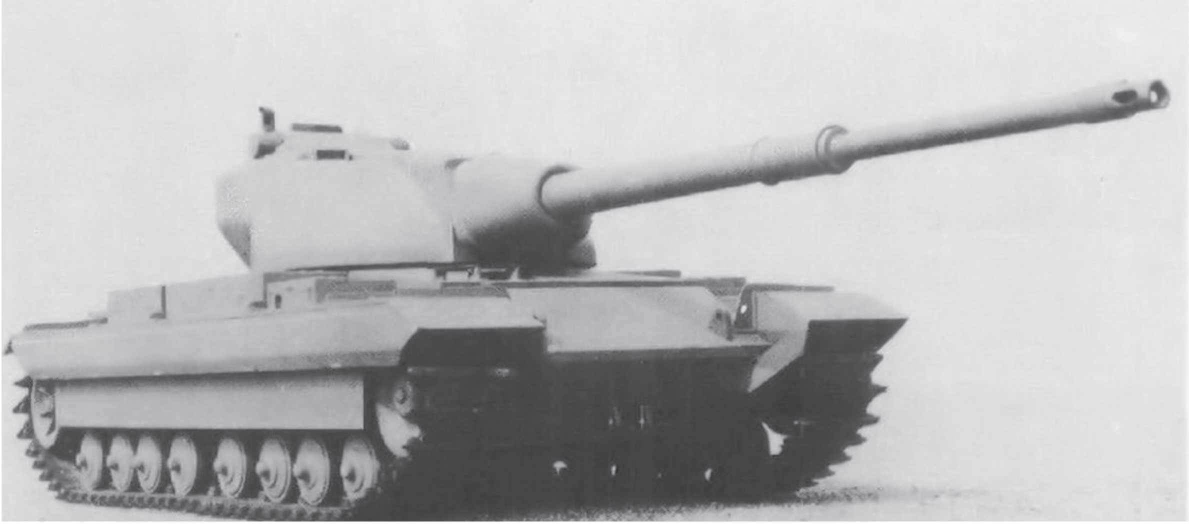
FV3808: SP gun
FV3809: 155mm SP gun

FV3802, FV3803 and FV3804 had five road wheels and were designed to use the same chassis; FV3805 and FV3806 had six road wheel layouts. Most of the variants were design proposals only and were not taken forward, but prototypes of FV3802 and FV3805 were built. One of the main reasons for the vehicles not being fully developed and fielded was the decision by NATO to standardize on 105mm and 155mm guns. The SP gun designs were based on configurations in which the main weapon was housed in an armoured enclosure at the rear with access hatches. To minimize changes to the design this effectively meant driving the Centurion-based hull in reverse with front-mounted sprockets. Therefore, in support of the programme, prior to prototype build, a Centurion hull was modified for driving in reverse mobility trials. When no longer required as a prototype vehicle an FV3805 was used as support vehicle for weapons trials at the Ministry of Defence Proof and Experimental Establishment at Shoeburyness.

A one-off conversion of a Centurion was a Mark 2 hull fitted with a Coles ST-10 for use at the Kirkcudbright firing ranges.

REME 27 Command workshops modified three Mark 3 vehicles for use as moving targets for training Milan, Carl Gustaf and 120 Wombat crews. Even though weapons with inert warheads were used, the kinetic energy (KE) of the weapon was such that up-armouring was required to ensure the complete safety of the crew, resulting in vehicles that weighed 60 tons.

CONQUEROR



Model of Conqueror displayed at the Royal Armoured Corps Conference, November 1951. (Crown Copyright MOD)

In 1944 Field Marshal Montgomery stated the requirement that the Army should move away from infantry and cruiser tanks to a single ‘Capital’ or ‘Universal’ Tank that was capable of both roles. This decision finally addressed the policy of using different types of tanks that, along with other factors, had contributed to British tanks being generally inferior to contemporary Germany vehicles for much of the war. At that time, as well as the A41, another new tank project was under way – the A45. This was being developed as an infantry support tank to complement the A41. It was to be fitted with a 20-pdr gun, rather than the 17-pdr on the A41, and had a design weight of 55 tons. Due to the work load at Chertsey, English Electric was appointed as the main contractor to help development. The prototypes were planned to be completed by mid-1946 and when the first hull was completed, it was fitted with an A41 turret. One unusual feature of the A45 was a remotely controlled machine gun on the front track guard. In light of Montgomery’s requirement, the decision was made that the new Universal Tank (which was designated FV201) would be based on the A45, rather than the A41. As the A41 Centurion was already developed and being fielded it was designated as the ‘Interim Tank’ until the FV201 could enter production. The decision to select the A45 rather than the A41 was driven by the view that the A41 could not carry the required levels of armour protection or be readily adapted to the other proposed specialist variants. At the 1947 RAC conference it was stated that FV201 would benefit from improved ammunition storage, a hull machine gun, improved gun and fire control, thicker armour and an additional crew member in comparison with the A41 Centurion. It was recognized that the FV201 would be heavier than the Centurion but the vehicle had wider tracks giving a lower ground pressure. As well as being bigger and having thicker armour the requirement for the gun tank version to have the built-in provision to be fitted with a dozer blade or be converted to a flamethrower variant in the field further increased the weight compared with the A41. The turret design was never finalized but was to be based on that of the Centurion but with a stabilized 20-pdr gun and a stereoscopic rangefinder for the commander. Initial automotive trials of the hull used a Centurion turret with plates added to represent the increased weight of the FV201 turret.

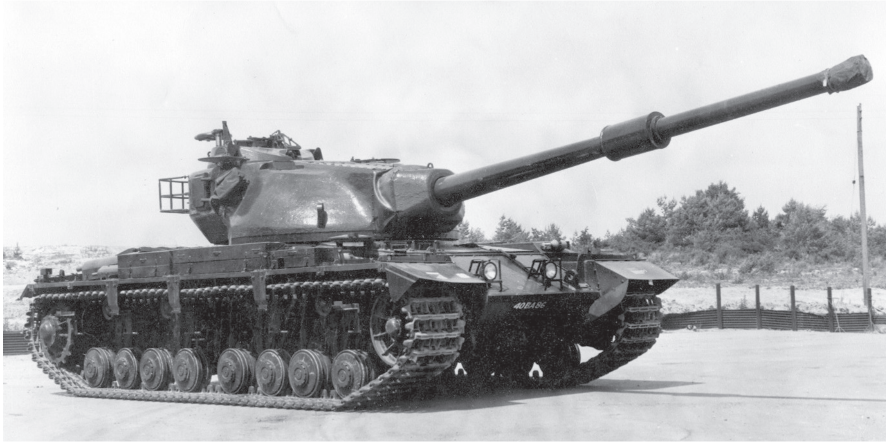
A number of variants were planned, these (with FV200 series designations) were:

FV201: Gun tank
FV202: Turreted with 6.5in. demolition gun and capable of being fitted with a dozer blade or mine roller
FV203: Armoured Vehicle Royal Engineers (Launcher) – AVRE(L). A multi-purpose engineer vehicle intended for a range of roles, including use as an Ark, transport of assault engineers, towing an equipment trailer or assault bridge and carrying and deploying fascine. It was also intended to be equipped with a 10-ton crane. Like FV202 it was intended to be capable of being fitted with a dozer blade or mine roller
FV 204: Flail gun tank
FV 205: SP medium anti-tank with a proposed 4.5in. gun
FV206: SP medium artillery
FV207: SP heavy artillery
FV208: Bridge layer
FV209: Armoured recovery vehicle
FV210 and FV211: Heavy and medium artillery tractors
FV212: Assault personnel carrier
FV213: Beach armoured recovery vehicle

A mock-up of the modified A45 design to meet the FV201 requirement was completed by June 1947 and inspected by the Army on 14 July 1947. Based on this, a mild steel prototype was built and was running by January 1948. The resulting vehicle weighed 55.9 tons – slightly over the target weight of 55 tons – had armour as thick as 152mm in places, and mounted a 20-pdr gun for which it carried 74 rounds. To cope with the increased weight in comparison to Centurion, the engine was to be an uprated Meteor engine generating 750bhp, although versions of the engine generating up to 860hp were being considered. Despite the higher weight the nominal ground pressure was kept lower than Centurion by the use of eight road wheels per side, instead of six on Centurion, and wider tracks at 914mm. Once the FV201 prototype was running, the mock-up was modified to represent the Duplex Drive amphibious version. Work also started on other variants with the FV209 ARV and FV203 AVRE being the most advanced with a mock-up on FV209 completed by July 1948. FV203 had a large superstructure with space to carry equipment or demolition crews and would have also formed the basis of the proposed heavy assault personnel carrier (FV212). Design of flame-throwing equipment went ahead and by early 1948 a pilot model trailer, weighing 12½ tons, was completed. The trailer carried 40 gallons of fuel and the system was designed to provide between 40 and 100 one-second shots with a range of up to 200 yards. The dozer blade solution was designed and a prototype built which was tested on a Centurion. A mock-up of the FV208 bridge layer equipment was installed on a Centurion hull which also had its side skirts mounted farther out to represent the increased width of the FV201 hull. Development of the weapon system for FV202 was carried out with 6.5in. and 7.5in. demolition guns fitted to a Churchill AVRE for trials in 1947; the 6.5in. gun was selected as it had the advantages of being easier to load, enabled more rounds to be carried and did not have a separate charge case that had to be disposed of when the round had been fired.

There were, however, growing questions about the performance of FV201 and other issues arose concerning the variants; for example, the flail tank required a longer hull to accommodate the engine and gearbox to drive the flail drum and neither the DD swimming version nor the bridge layer would be able to operate from the new Tank Landing Craft Mark 8. Due to the conflicting requirements and resulting design challenges, the decision was made in November 1948 not to have a single 'Universal Tank' but to develop a new medium gun tank (FV221) and a new heavy gun tank (FV214) with the Centurion adopted as the standardized tank until the new designs could be developed. The FV201 project was formally ended in July 1949 and the decision for the way ahead endorsed at the Royal Armoured Corps conference in November 1949. The first FV201 prototype had completed 1,591 miles by the time the project was cancelled. Work on the specialist variants of the FV201 also stopped with the intention that requirements would, for the interim, be met by existing Churchill Tank-based systems or new solutions based on the Centurion. By that stage the FV203 prototype had been completed and had carried out 200 miles of running. At this time, neither the FV214 nor the FV221 were envisaged as having flamethrower versions, despite this remaining as a firm army requirement, and so some study work was undertaken on a Centurion-based system. One driver for the flamethrower requirement was its intended use against dismounted soldiers armed with the Panzerfaust, or similar, rocket-propelled anti-tank systems. This had become a dominant threat towards the end of World War II with the proportion of British tanks disabled by this weapon rising from 10 per cent in Normandy to 55 per cent during the final drive into Germany. The Army Operational Research Group (AORG) issued a report (AORG 12/48) in November 1948 which assessed that flamethrowers were very effective against the Panzerfaust threat at ranges up to at least 60 yards.

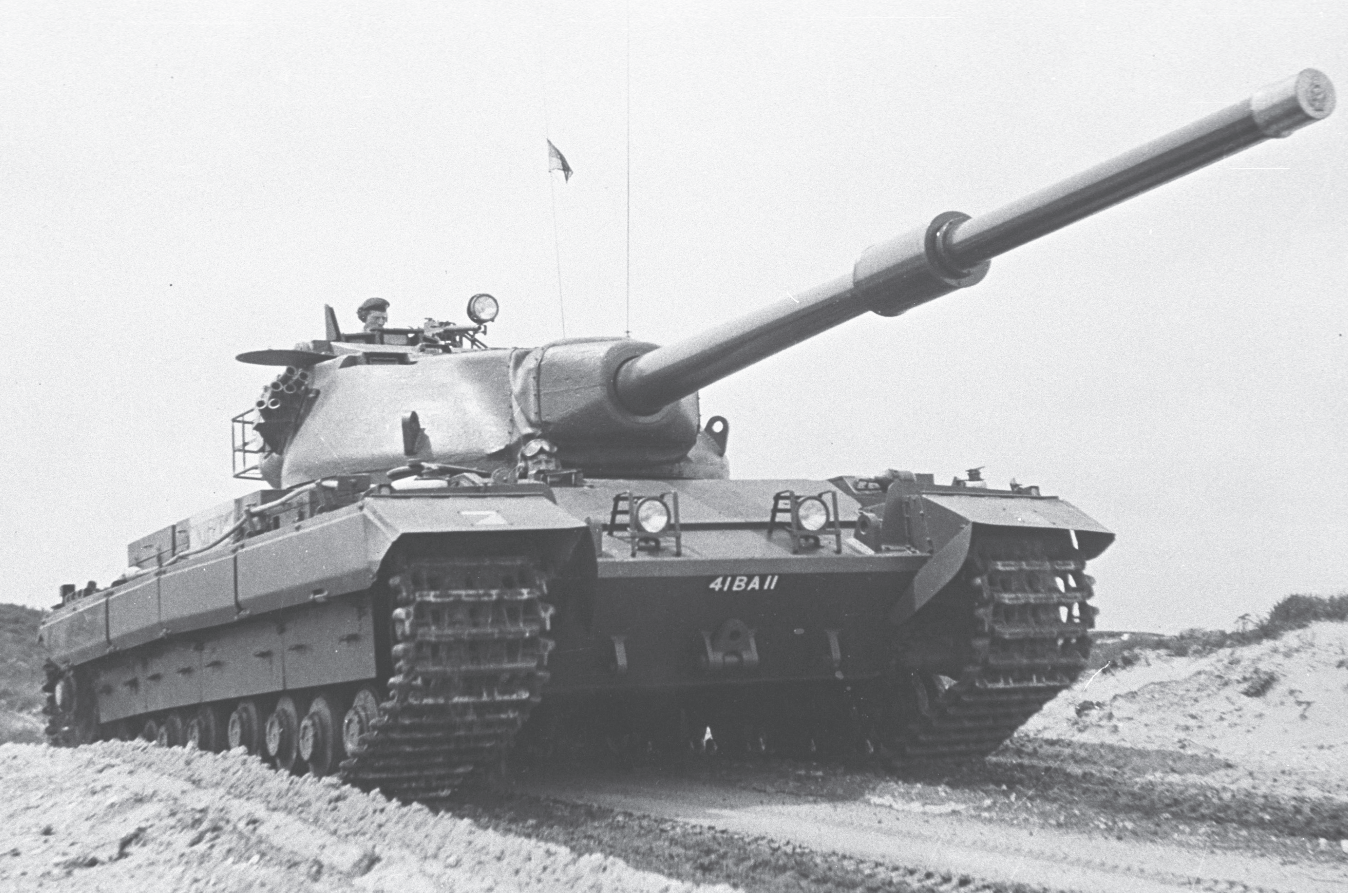
The driver for the FV214 heavy gun tank was the requirement to defeat heavy Soviet tanks at range, as the Centurion was viewed as being 'out-gunned' by the Joseph Stalin III tank. At the 1949 RAC conference the Director Royal Armoured Corps stated that the FV214 was to be a medium tank chassis carrying a heavy gun, hence was a 'Heavy Gun Tank' and not a 'Heavy Tank'. The designs for the new vehicles, the FV221 and FV214, were to be based on the FV201 although it was envisaged that the FV214 would carry at least 1 ton of additional armour. A further requirement was that it should be possible to convert the FV221 to an FV214. Work started on developing requirements and concepts for the new heavy tank and consideration was given to reducing the turret crew to two men with the commander also acting as the gunner. The two-man turret crew was seen as a way of reducing turret size, and hence weight, and so enabling even more armour protection to


Conqueror with side skirts removed. (The Tank Museum, Bovington)

be provided; however, the loss of a crewman was seen as too much of a disadvantage especially for servicing the vehicle.

In 1951 it was confirmed that the FV201 hull would be used as the basis for the heavy gun tank and the decision was made that it would mount the US L1 120mm gun. Some concept work had already been undertaken during the FV201 development programme looking at versions with larger-calibre guns. These included initial concepts for a 120mm armed ‘heavy tank’ version of FV201 weighing 56.2 tons and carrying 40 rounds of ammunition and with a turret race ring of 80 inches (203cm). Another concept was for a heavy tank with a 155mm gun; this vehicle would have had the weapon in a limited traverse turret on a 100in. (254cm) race ring. It would have had 30 stowed rounds and weighed 60.8 tons. This earlier concept work was refined and developed and resulted in the initial design for the FV214 Conqueror Tank. The hull required limited modifications from the original FV201 hull and could be slightly shorter as the requirement for a power take-off to power the dozer blade and other equipment was dropped. The requirement for a DD swimming version was also dropped. The hull glacis was simplified and sloped back more, thus increasing the protection provided, and the 5th crew member in the hull was removed to make more room for ammunition and again simplifying the design by removing the need for the crew hatch. The track skirts were also changed from the flat, Centurion-like plates on the FV201 to a shaped-plate arrangement that was set inboard over the suspension units. One other change was an increase in the power of the Meteor engine from 650hp to 810hp to cope with the increased weight – which was eventually 65 tons. The increased power was achieved through the use of direct fuel injection and gave a top speed of 34kph and a range of 155km. More challenging was the design of a completely new turret to mount the 120mm gun and stowage to carry enough of the bulky ammunition. Development of the turret therefore lagged behind that of the hull. By June 1953 four prototypes and ten pre-production vehicle hulls were well advanced despite the lack of a final turret design. At that time the Prototype 1 hull was undertaking automotive trials at FVRDE with a weighted superstructure to bring it up to 65 tons. Prototype 2 was also at FVRDE and being used as a gun and fire control system development vehicle. Prototypes 3 and 4 were largely complete but awaiting electrical and gun control equipment. In addition to the four prototypes a fully representative vehicle hull and turret was built at FVRDE for use as a target in protection assessment trials. When they became available, the first five pre-production vehicles P5 to P9 were also delivered to FVRDE without turrets, to be available for additional automotive and reliability trials.

The development of the proposed new medium tank (FV211) did not go ahead as it was quickly realized that it would provide few performance benefits over Centurion. Rather confusingly, the FV211 designation was initially used for FV214 hulls fitted with an adaptor ring to take a Centurion Mark 3 turret; the resulting vehicle was subsequently designated FV221 Caernarvon. To add to the confusion of terms it was also referred to in some official documents as the 'Interim Tank'. In November 1951 the stated plan was to manufacture 50 FV221s. In the end only 21 were built, the first five FV221s being based on the FV214 pre-production hulls P10 to P14. The main aims of fielding the Caernarvon were to demonstrate and prove the new engine and give the army experience of operating such a heavy vehicle while the turret was developed. Due to the resulting confusion of the terminology, at the November 1952 RAC study event the Director Royal Armoured Corps had to stress that the FV221 was definitely NOT an interim tank but a training vehicle issued in advance of the FV214 and referred to it as an FV214 prototype. A number of the FV221 vehicles were issued to operational units, including two sent to the 14/20th Hussars in the Middle East where they successfully completed a total of 2,000 miles of running. Some vehicles were fitted with a dummy barrel extension to simulate the increased length of the 120mm gun to be used on FV214.



Conqueror gun tank. (The Tank Museum, Bovington)

Following extensive testing of the four full Conqueror prototypes at FVRDE, 20 Mark 1s were manufactured and issued to the BAOR early in April 1955.

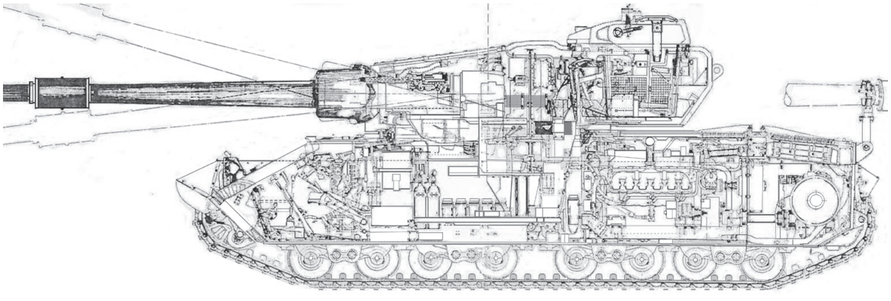
The Conqueror had a conventional overall layout with a central turret, front driver's compartment and rear engine and transmission driving rear sprockets. The suspension was of the Horstmann type but it had eight small road wheels per side. Construction of the hull consisted of welded armour grade steel. The turret was based on a large well-shaped casting. The commander was positioned at the rear of the turret with his own cupola and was largely isolated from the gunner and loader. Despite the large size of the turret one shortcoming of Conqueror was the limited depression of the main armament which constrained its use in defensive reverse slope locations.

The main characteristics of Conqueror were:

Weight: 65 tons
Length: overall 11,887mm, hull 7,849mm
Height: 31,623mm
Width: 3,988mm
Engine: Meteor Mk1A 810hp at 2,800rpm
Transmission: Merritt Brown Z52
Maximum speed: 34.3kph
Range: (road) 160km
Track: (width) 787.4mm
Armour: (maximum) 200mm

Although not quite as heavy as the World War II German Tiger 2 tanks, at 65 tons, it was the heaviest tank in operational service with any army at the time, and significantly heavier than any previously fielded UK tank.

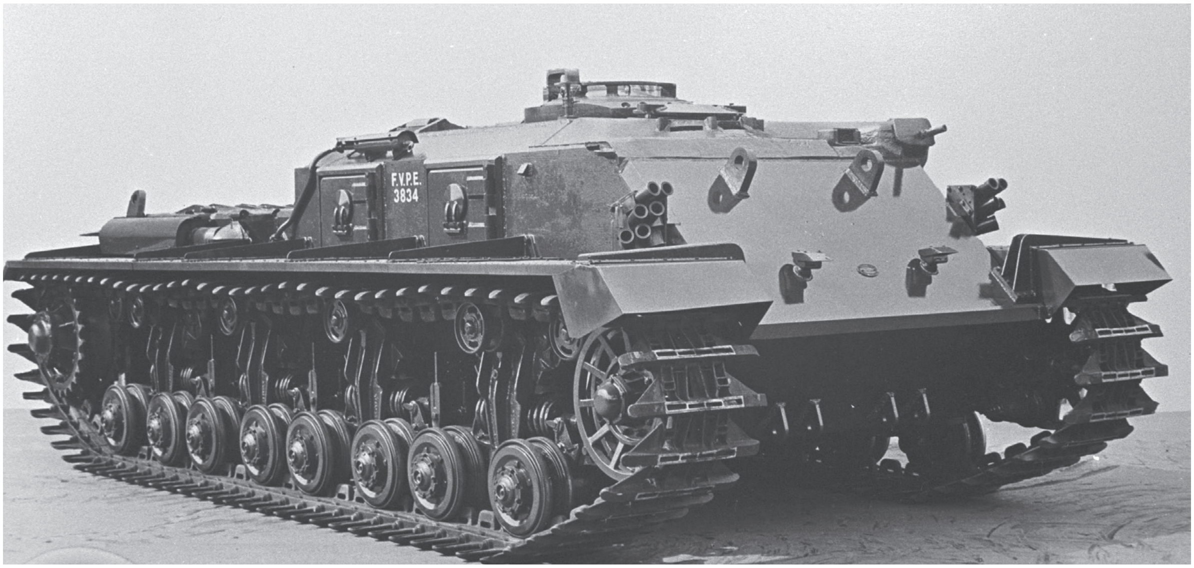
The Conqueror was the first tank to use the concept of a 'Hunter-Killer' mode where the commander would acquire a target and then hand it over to the gunner to engage, while he then searched for the next target. The handover process was automated so that, when commanded, the system would automatically slew the gunner's sight until it aligned with that of the commander. This system of target acquisition and engagement became standard on all subsequent UK Main Battle Tanks. In order to improve accuracy the commander was provided with a coincidence rangefinder. The Fighting Vehicles Research and Development Establishment continued development work on the gun and fire control system and this resulted in the Mark 2 which had a much-simplified crew interface. Other minor changes were introduced to the Mark 2 following experience with the 20 Mark Is; these included replacing the driver's three episcopes with a single episcope, changes to the driver's hatch and improvements to the cooling system. A total of 165 Conqueror Mark 2 vehicles were built, the majority



Conqueror cross-section drawing showing lay-out of internal components. (Crown Copyright MOD) at ROF Dalmuir, over a period from 1955 to 1959. Conquerors were issued as replacements for the M10 tank destroyers in the divisional armoured regiments which had one squadron of Conquerors to two squadrons of Centurions. Other regiments had Centurions only. Conqueror was withdrawn from service in 1966 when Centurion with the L7 105mm gun became widely available.

Although the Conqueror was the first UK tank to use two-piece ammunition, there were concerns when it entered service about the ability of the loader to cope with the heavy rounds in the hot confined spaces of the vehicle and there were reports that loaders could only manage between seven and 15 rounds before becoming too fatigued. To investigate this issue a series of trials were undertaken at Lulworth between 16 and 20 June 1956. Called the ‘Conqueror Loader Fatigue Trials’ they investigated the overall target engagement rate against a realistic target array at representative ranges, and hence ability of loaders to cope with the required rate of fire in a typical tactical situation. The trials were carried out under different conditions of hatches open and closed. In addition, the effectiveness of the fume extractor was investigated by sampling and analysing the internal air. The results were varied but the time taken to engage 16 targets varied from 9 minutes 43 seconds to 16 minutes 41 seconds. The typical minimum time between targets was around 23 seconds with loading taking around 14–15 seconds. Some loaders went on to load 34 rounds in under 45 minutes; hence demonstrating that the vehicle would have been a potent counter to a mass attack by heavy Soviet tanks.

A number of variants of Conqueror were proposed including a Flail Tank (FV216), an SP Medium Anti-Tank weapon (FV217) and an Ark (FV223). However, the only variant of the Conqueror which reached production was the Armoured Recovery Vehicle (ARV). Two versions of the ARV were fielded; eight Mark 1 (FV219) and 20 Mark 2 vehicles (FV222). The Mark 1 consisted of the basic tank hull with a square box-like structure in place of the turret, which was similar in appearance to that on the Centurion Mk 2 ARV. This structure housed the winch and recovery equipment. A mock-up of the Mark 1 was completed in 1953, following which full development started. The Mark 2 had a purpose-built hull with a sloping glacis plate extending to the top of the winch housing, providing better accommodation and visibility for the crew as well as improved protection. Both versions were fitted with a winch

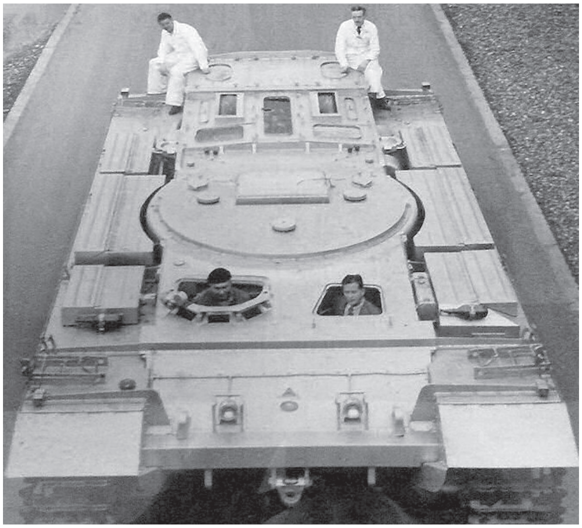


Conqueror Armoured Recovery Vehicle Mk 2. (The Tank Museum, Bovington)

powered by the tank's main engine. The winch design was based on that used on the Centurion but uprated from a 30-ton pull to 45 tons. A spade was provided at the rear to act as an earth anchor while winching.

One proposed variant of the Conqueror which was the subject of extensive design studies and investigation was the FV215 Heavy Tank which is described in the next section.

A one-off research vehicle based on Conqueror was a hull fitted with a gas turbine. Built in 1954 it utilized a non-standard prototype FV221 hull as indicated by additional crew hatch in the hull next to the driver. Initially a PU2979 600hp unit manufactured by C. A. Parsons and Co. was fitted and later a more powerful version was used. The fit took up much of the fighting compartment – so the turret was removed and overall the use of a gas turbine not considered a success. The vehicle made its first public appearance at a vehicle demonstration at FVRDE on 30 September 1954 for which a press release stated, 'A special feature of the demonstration was the first appearance of the first heavy tracked vehicle to be powered by a gas turbine, which was developed and made in this country.' This statement was not totally accurate for, although the Conqueror provided what can be considered to be the first successful demonstration of a gas turbine-powered heavy tank, an experimental unit had been fitted to a 70-ton German Jagdtiger in 1945. This vehicle undertook very limited running and with its turbine exhaust

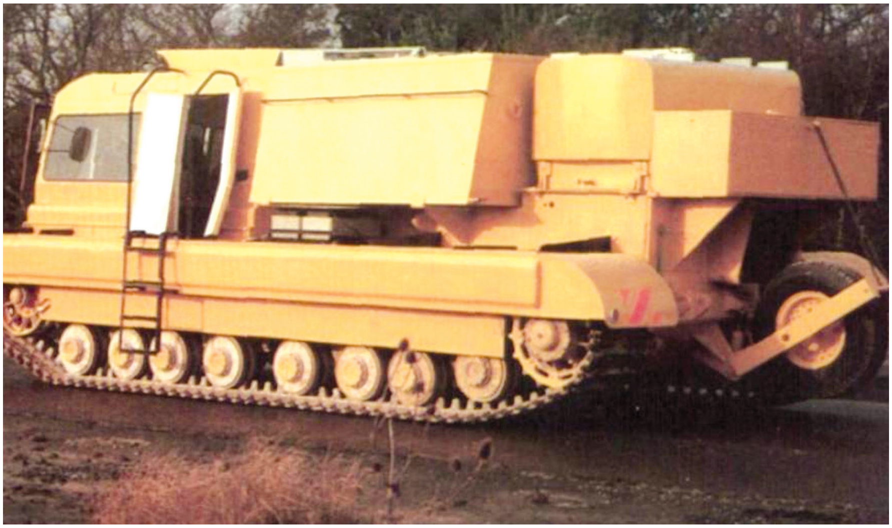


The Gas Turbine Conqueror at Chertsey. The role of the staff sitting on the back is not known! (Crown Copyright MOD)

exiting vertically at a temperature of 650°C it was notorious for burning trees in the secluded test area in Austria. The designer of the engine used in that vehicle, Alfred Muller, and the engineer who designed the installation, Otto Zadnik, moved to the UK and worked for C. A. Parsons and Co. after the war and so were able to use their experience to design the Conqueror engine and installation.

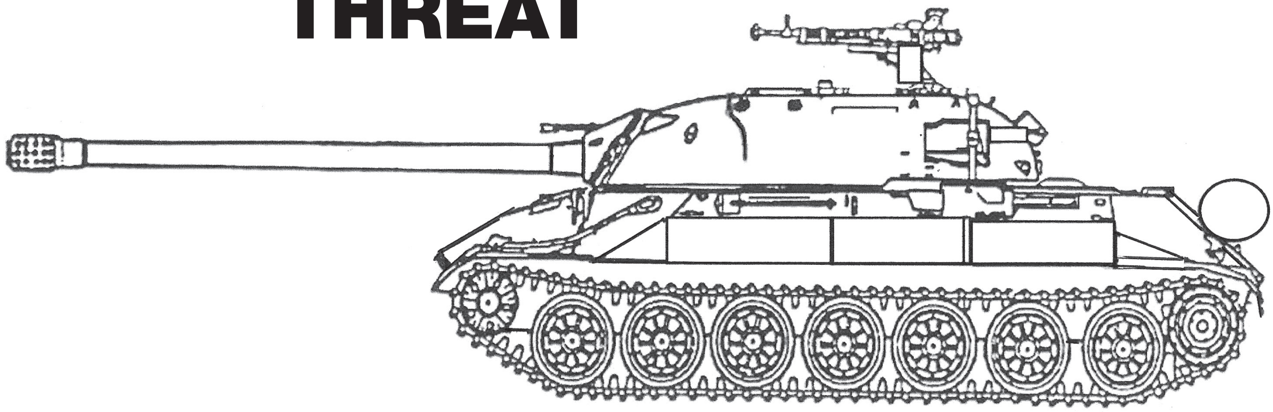
Another one-off conversion of a Conqueror prototype was into a Dynamometer Car used by MEXE at Christchurch for measuring the drawbar pull and winch performance of engineering and plant equipment. This vehicle was based at the MEXE test ground at Hurn. The vehicle was later fitted with a Rolls-Royce diesel engine and Chieftain tracks. The vehicle was subsequently passed to the Bovington Tank Museum where it was fitted with an observation cabin.

Another ex-Chertsey Conqueror ended its days at the Ministry of Defence Weapon Proof and Experimental Establishment at Shoeburyness where it acted as a mobile platform. It was used with a number of land and naval weapons and was used as a surrogate hull for trials of the turret for the SP70 155mm self-propelled gun.



Conqueror dynamometer car built by the Military Engineering Experimental Establishment. (Crown Copyright MOD)

COUNTERING THE SOVIET TANK THREAT

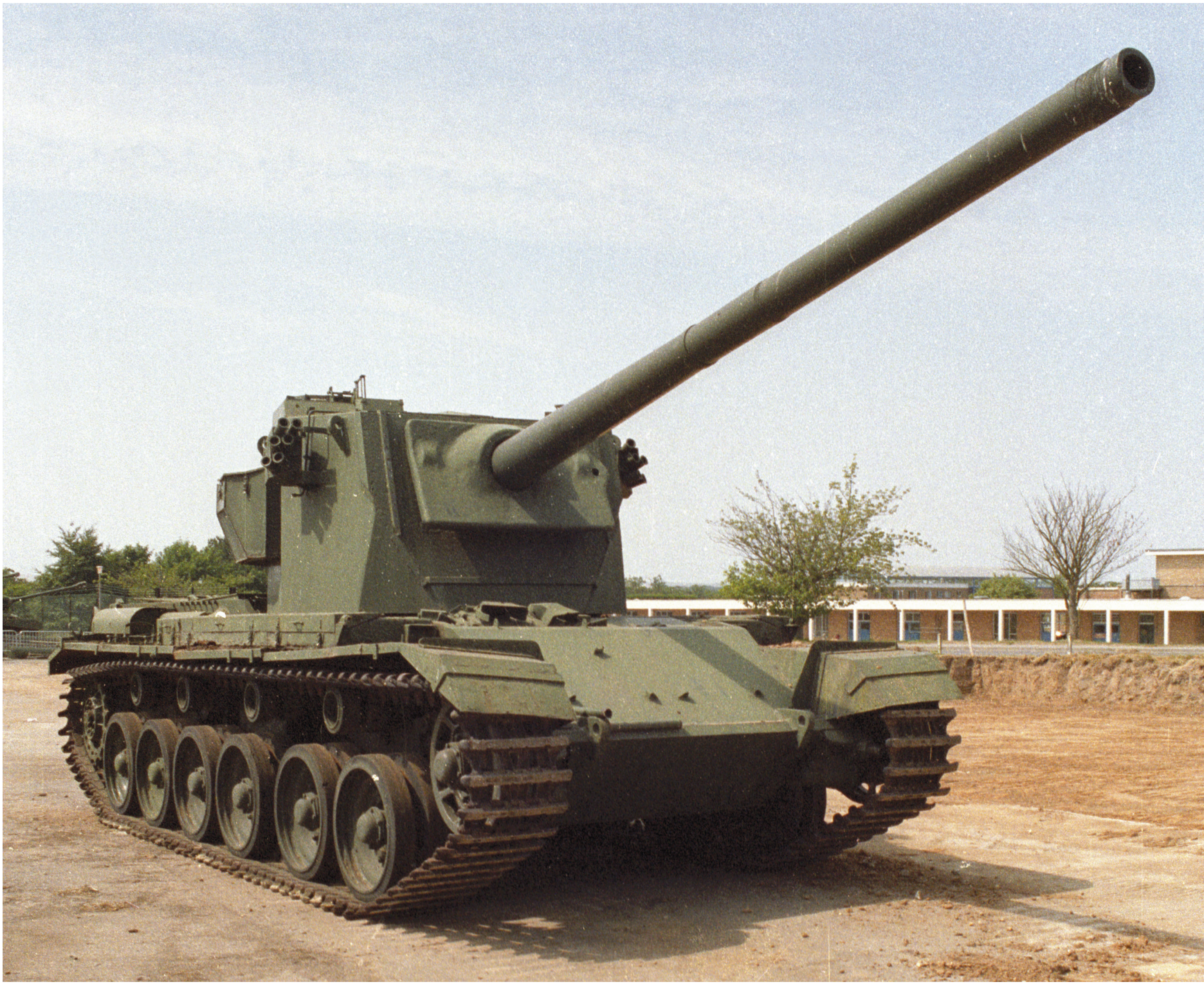


Soviet IS7 Heavy Tank. Only prototypes were manufactured. (Author's Collection)

The FV214 Conqueror had been developed as a counter to the threat from Soviet heavy tanks. The Soviet Joseph Stalin 3 (IS-3) had been publicly displayed in a victory parade at Berlin in 1945 and with its thick armour, rounded turret shape to optimize protection, and 122mm gun it was seen as a significant threat to contemporary British tanks. Following some redesign work to address shortcomings, which included strengthening the hull and final drive, around 1,800 IS-3s were manufactured at the Chelyabinsk plant. The IS-4 was an improved version of the IS-2, which had seen action in World War II, with thicker armour and a more powerful engine; this was accepted for production in 1947 although only 200 were manufactured. Totally new designs of heavy tanks, the IS-7 and IS-8, were also developed, and it was the IS-8 that went into production in 1951; having been re-designated as the T10 following the death of Stalin. The T10 had even thicker armour than the IS-3 and an improved 122mm gun. By 1962, when production ended, around 8,000 T10s of various Marks had been manufactured. Thus, the IS-3, T10 and assumed future development of further heavy tanks for the Soviet Army remained a source of ongoing concern. Activities to counter the threat from Soviet heavy tanks resulted in a number of alternative concepts and designs being considered in the late 1940s and early 1950s, both as interim solutions during the development of the Conqueror, and as future developments to respond to the expected new and more heavily armoured and armed threats.

One interim solution that reached the prototype stage was the FV4004. Called the Centurion 120, or Conway, only one was built. Based on a Centurion 3 hull it mounted the same L1 120mm gun as the Conqueror and was intended as a stopgap until that vehicle was fielded. The gun was installed in a tall, relatively lightly armoured turret and only 20 rounds could be carried. In November 1951 initial plans were developed to field 25 in financial year 1952–53 and 150 in financial year 1953–54; but by late 1952 it had been decided that the limitations were such that it would not go into production. The army wanted a solution with a much lower silhouette and so work began on concepts for a limited traverse 120mm gun on a Centurion-based hull; but this was soon stopped as it was diverting effort away from the more pressing design and development activities in support of FV214. Not directly related was a much later feasibility study carried out in 1974 covering the integration of the L11 120mm gun into Centurion 5, but with the Chieftain in service it was not taken forward.

A vehicle developed at Chertsey at that time that did enter production was the Charioteer (FV4101), which started to enter service with Yeomanry regiments in 1953. At that time there was a surplus of 20-pdr guns of the type being fitted to Centurion and so fielding Charioteer was a stopgap solution for providing the BAOR with more firepower until Conqueror was fielded. The initial proposal was to develop a lower-cost tank to supplement Centurion, designated FV1066, but this idea was quickly dropped in favour of the even lower-cost option of modifying existing vehicles. The FV1066 design concept was considered further in 1956 but only as a design study for the Tank Technology officer course at the School of Tank Technology where it was called the Senlac. In terms of available existing vehicles to mount the 20-pdr gun, Comet tanks were an obvious choice but these were still required by the Field Army; hence the solution was based on a modified version of the Cromwell with an enlarged turret ring. Initially the vehicle was referred to as the Cromwell 20-pdr and in November 1951 the Royal Armoured Corps stated a requirement for 630 vehicles; although by November 1952 this had been reduced to 400. A challenge for the FVRDE design team was to develop a solution that enabled the upper hull to be modified for a larger turret ring with no impact on the lower hull which housed the suspension units. The resulting vehicle had a crew of three; driver, loader/radio operator and commander/



FV4004 Conway with its large turret mounting a 120mm gun on a Centurion hull. (The Tank Museum, Bovington)

gunner. To keep the weight within the limits of the Cromwell hull the turret was only thinly protected with 37mm-thick armour on the front and 25mm on the sides. Twenty-five rounds of 20-pdr ammunition were carried of which eight were stowed in the turret. Eventually around 400 Cromwell tanks were converted to Charioteers in 1953 and 1954 with the work carried out by Robinson and Kershaw Ltd of Dukinfield in Cheshire. It only remained in British Army service for around four years. However, it was supplied to a number of other countries including Finland (38), Austria (82), Jordan (49) and

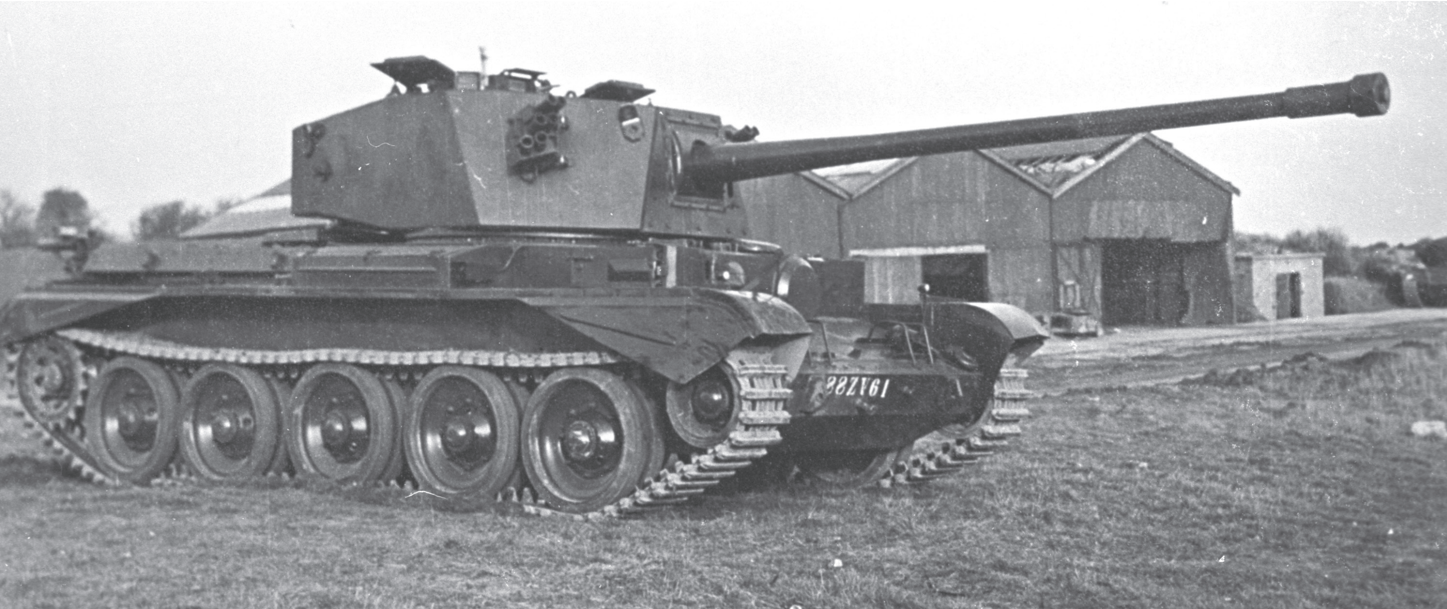
Lebanon (20) with some seeing action in the Six Day War of 1967. Some of the turrets from vehicles supplied to Austria would be subsequently used in fixed fortifications constructed between 1963 and 1965. In 1959 Chertsey successfully designed and tested a version fitted with a 105mm L7 gun. Following preliminary trials at Shoeburyness it was taken to Kirkcudbright where it undertook trials to assess the impact of the larger weapon on suspension, crew and accuracy. The trials confirmed that, despite the light chassis, it was almost as accurate as the 105mm on the Centurion and, subject to minor changes to the gunner's sight pad, it would be acceptable for service use.

As already mentioned, a vehicle based on the Conqueror was planned as a Heavy Gun Tank Mark 2, designated FV215. In order to meet the expected future Soviet Heavy Tank threat it was to be armed with an even larger gun than the Conqueror. Following analysis and trials at the Armaments Research and Development Establishment (ARDE) at Fort Halstead, it was assessed that a gun of around 180mm calibre would be required to defeat the frontal armour of Soviet heavy tanks at the required ranges. Therefore the 183mm L4 gun and associated HESH ammunition was developed. The formal requirement for a tank destroyer mounting this weapon, to defeat the expected successor to the Soviet JS3 and T10 tanks, was stated in a document dated 9 September 1950. This called for FVRDE to undertake a study into four options:

1. A heavy tank with the 183mm gun mounted in a turret with full 360-degree rotation.
2. A self-propelled anti-tank gun with a limited traverse weapon protected by heavy armour.
3. A self-propelled anti-tank gun with a limited traverse weapon with splinter protection only.
4. A self-propelled anti-tank gun with a limited traverse weapon and no protection.

The study reported on 23 July 1951 and concluded that although a vehicle with a turret with full protection and 360-degree rotation was the most desirable solution, the size of the gun made that impractical. It was therefore recommended that a system with more limited traverse but heavy frontal armour be developed. Design work started and a contract to support the development was placed with Vickers-Armstrong. By 1954 the design work was proceeding well and a target design specification had been developed and issued on 1 April that year. Fitted with a limited traverse turret the resulting design for FV215 was more of a super heavy self-propelled anti-tank weapon (SPAT) than a true tank. The hull was designed to be around 300mm narrower than Conqueror, but 100mm longer and the overall vehicle height 90mm greater, the reduction in width thought necessary to keep the weight similar to that of Conqueror at around 65 tons. It mounted the 183mm gun in a rear-mounted turret with limited traverse over an arc of +/-45 degrees. The engine was located between the driver and fighting compartment in order to keep the centre of gravity as close to the centre of the vehicle as possible – something not feasible with a conventional arrangement with a centrally mounted turret. A coincidence rangefinder with a 6ft (1,829mm) base was to be fitted. The turret was to have 200mm frontal armour but relatively thin, 17mm, armour around the sides and rear. The crew was to include two loaders supported by a flick rammer to load the rounds, which weighed around 72kg. The engine cooling air was drawn under the floor of the fighting compartment in an effort to provide some degree of cooling. On 9 September 1954 the overall concept was well defined and reviewed at the fourth design meeting. The Army requested a number of improvements to the design be explored including:

1. An increase in stowed rounds. The Army required 20 rounds whereas the concept had 15 ready rounds with the ability to carry three more.



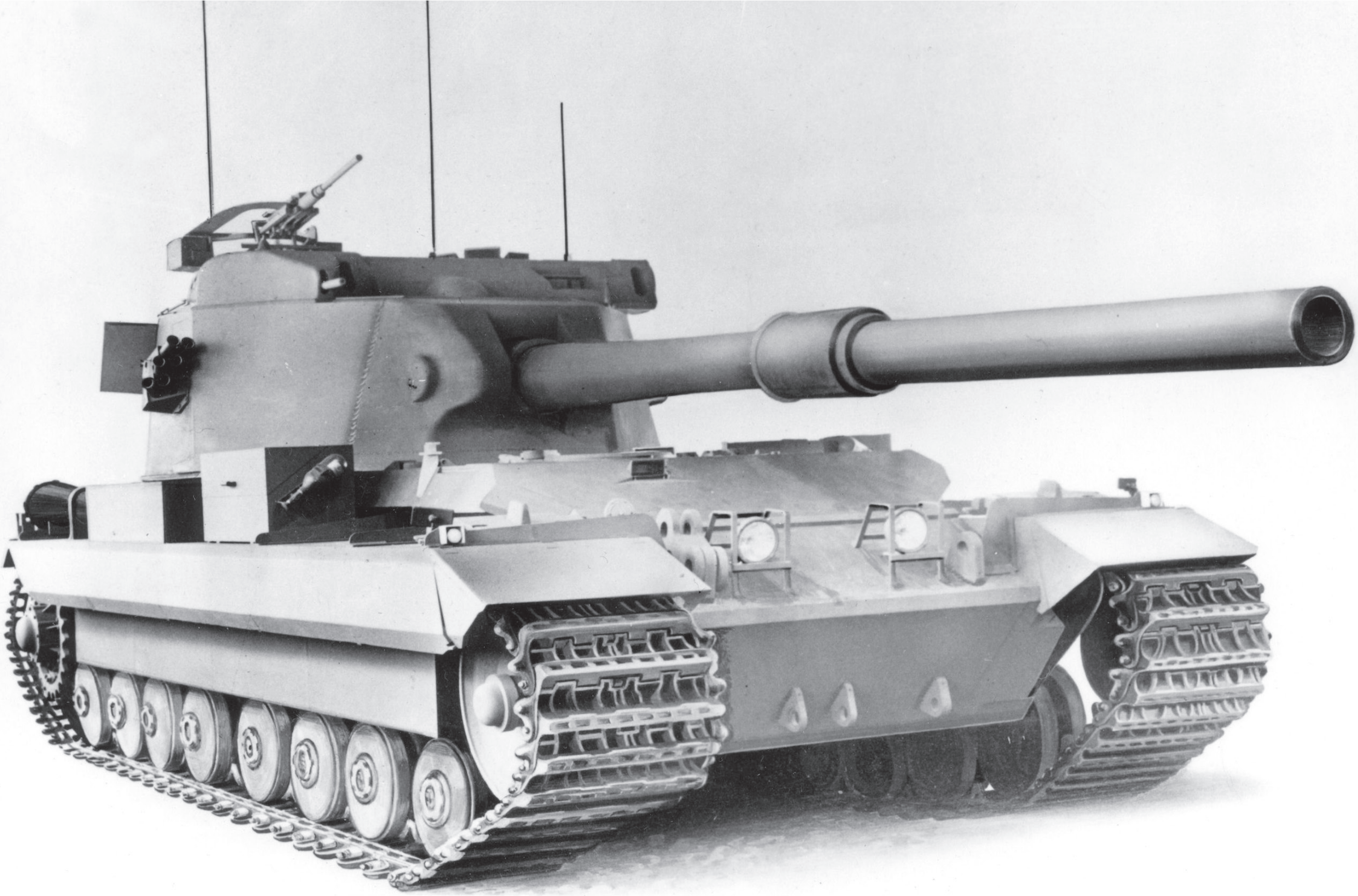
FV4101 Charioteer. A stopgap solution based on a Cromwell hull to bring more 20-pdr guns into service. (The Tank Museum, Bovington)

2. An increase in gun traverse speed which was around 6 degrees/second. A target of 12 degrees/second was set which brought it closer to the 15 degrees/second of the Conqueror.
3. The ability to fire over the rear of the vehicle – this was not possible because, although the turret could rotate to the rear, there was no turntable and it was not possible to load the weapon when facing that direction.
4. Revised track skirts that allowed easier access to the running gear for maintenance. The running gear and track skirts were the same as for Conqueror and the same request had been made for that vehicle.

It was agreed to proceed with the design and build of a full-scale wooden mock-up. The mock-up was completed but the project was stopped in 1957 with a project closure report being issued on 1 October that year. By that time analysis had shown that although the 183mm gun had significantly more killing power at range, its accuracy limitations and low rate of fire meant it provided limited benefits over the Conqueror. In addition, cuts in the defence budget and a view that long-range engagement of Soviet armour would be better carried out by platforms mounting guided anti-tank missiles sealed the fate of FV215.

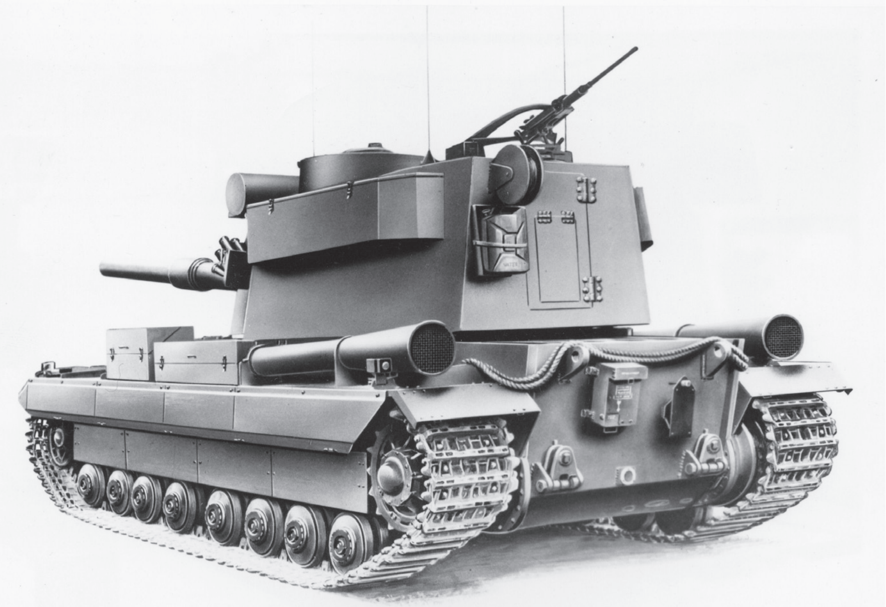
At the time the FV215 project was wound up the design was about 80 per cent complete and the predicted characteristics of the vehicle were as follows:

Weight: 65 tons battle weight, 61 tons unladen
Length: overall 9,900mm, hull 7,821mm
Height: 3,200mm
Width: 3,660mm
Width over tracks: 3,554mm
Ground clearance: 508mm
Gradient: 35 degrees
Step: 914mm
Engine: Meteor Mark 12 giving 810bhp
Maximum speed: 32kph
Main weapon: 183mm
Elevation: 15 degrees
Depression: 7 degrees



ABOVE
FV215 Heavy Gun Tank Mark 2 mock-up, ¾ front view. (Crown Copyright MOD)

RIGHT
FV215 Heavy Gun Tank Mark 2 mock-up, ¾ rear view. (Crown Copyright MOD)



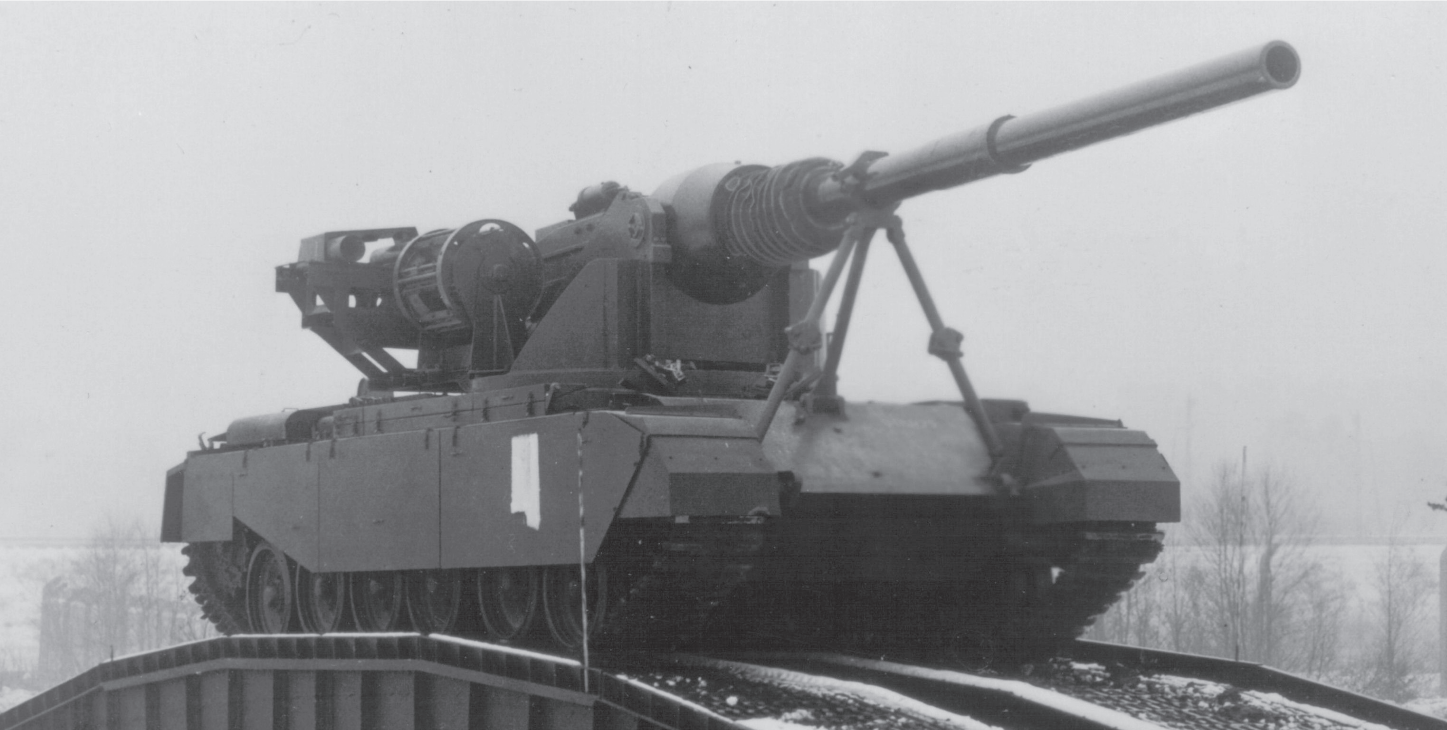
Traverse: +/-45 degrees
ARMOUR PROTECTION:
Hull glacis: 125mm sloped at 59 degrees
Hull side: 44mm plus 6mm track skirts
Turret front: 254mm (proof against 100mm armour-piercing rounds at 457.2m over +/-30-degree frontal arc)
Turret rear: 17mm
Turret roof: 32mm

As part of the work to assess the performance and risks associated with such a large weapon on a mobile platform a demonstrator vehicle was built. Completed in 1955 it mounted the 183mm weapon on a Centurion hull and was used for trials. As with the proposed design of FV215 the gun could be traversed over an arc of +/-45 degrees. One of the other purposes for the FV4005 was to act as a test bed for developing an automatic loader. As well as the automatic loader, conventional hand loading was investigated. Even with two loaders, as proposed for the FV215, it took 25–30 seconds to load and fire each round. The resulting rate of fire of just over two rounds per minute, compared with 4–5 per minute with Centurion, was considered too slow. Another issue with the 183mm gun was that it was designed to fire HESH rounds which have a lower muzzle velocity than armour-piercing rounds; hence they have to be fired at greater elevation angles and are more susceptible to crosswinds and so have a lower accuracy. When work on FV4005 started there was an aspiration that it could be rushed into service as a stopgap if required and two further prototype vehicles were manufactured which had a splinter-proof turret, similar to that of the Conway, made of 14mm armour plate. The turrets were designed and built at Woolwich and subsequently tested should the need to go into production arise. As with the initial prototype the turrets were mounted on Centurion hulls and the resulting vehicle weighed 50 tons. The project ended in August 1957, by which time test firings of over 150 rounds had been carried out.

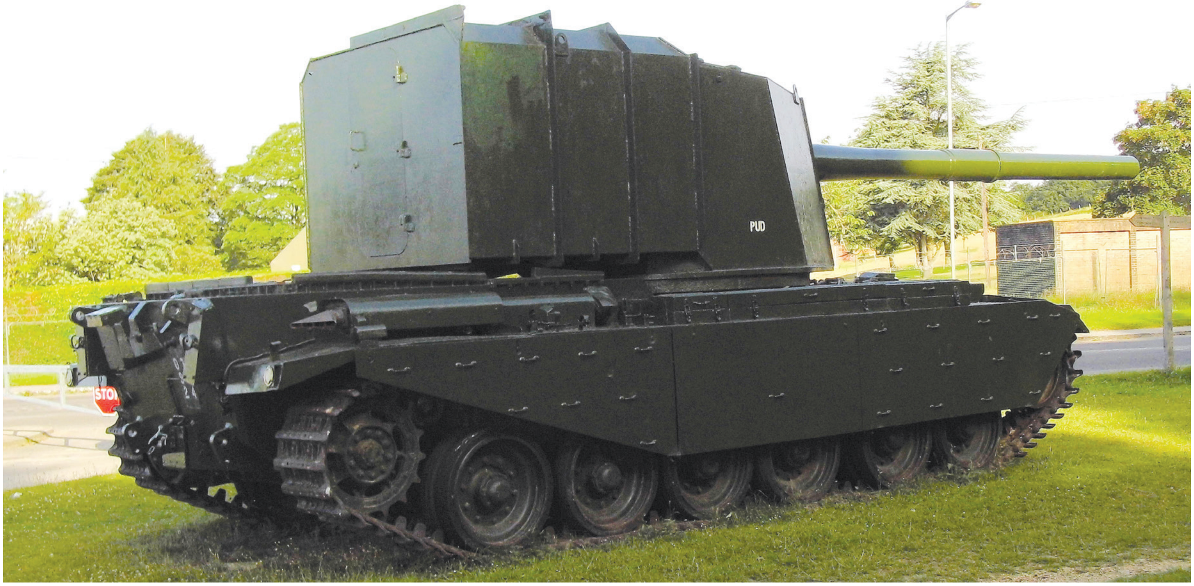
Despite not entering production, the FV4005 can still lay claim to being the largest-calibre self-propelled anti-tank weapon ever made.

The use of HESH rounds was seen as being key to the ability to defeat heavy Soviet tanks at range. An HESH round consists of a plastic explosive encased in a thin wall casing. On impacting with armour the explosive is squashed against the surface of the armour and spreads out to form a disc of explosive which is then detonated by a base fuse. This generates a compression wave which travels through the armour and interacts with the inner face to generate high-velocity scabs of metal inside the targeted vehicle. This mechanism worked well against the thick homogenous armour as used on the heavy Soviet tanks of that time. During the late 1940s and early 1950s there was a significant effort assigned to the development of HESH rounds at the ARDE, with much of the early work led by a Mr Woolcock. Research and development work included solutions for the Battalion Anti-Tank Weapon (BAT), an anti-tank HESH round for the 25-pdr gun and HESH anti-concrete rounds for firing from larger-calibre artillery weapons. HESH rounds were developed for the 120mm and 183mm guns for which a challenge was ensuring that the rounds could survive the launch from a high-pressure gun and still function as required at the target end.

The 120mm HESH was developed as an alternative round to the APDS used with the L1 gun and had to be designed to be compatible with the existing US gun design. There was also concern that, as the ammunition was two piece, the HESH round might have to survive the incorrect use of the higher-pressure charge used with the APDS round. Initial trials of a round design were undertaken in 1950 but it was shown that at very high-impact velocities the fuse did not have time to function correctly, hence work was required to optimize the round velocity to ensure it was slow enough to function correctly on impact but was still high enough to give an acceptably high probability of hit. A revised



FV4005 183mm anti-tank gun demonstrator. Based on a Centurion hull it is referred to as S.P. Heavy Anti-Tank No.1 in some documents. (Crown Copyright MOD)



The 183mm gun in the splinter-proof turret, as mounted on a Centurion hull at the Bovington Tank Museum. (Author's Collection).

design was tested in 1951 and this could defeat over 150mm of armour at 60 degrees, hence this formed the basis for a version that could be approved for service use.

A requirement for a weapon of around 180mm was identified in 1949 and work started soon after. The actual calibre adopted was 7.2 inches (183mm) – this was selected so that an existing howitzer could be used for development trials – but the designation 180mm continued to be widely used. In 1950, trials of a development round were undertaken using an up-armoured Centurion as the target. This was described as being 'well-overmatched' with the round defeating 230mm of armour steel at 60 degrees. Following the success of the firings from the relatively low-pressure howitzer, work on a version suitable for firing from a high-pressure anti-tank weapon was started.

In the 1950s, with a number of different vehicles being fielded, developed or the subject of design studies, it was necessary to understand the relative cost-effectiveness of the different potential solutions. Decisions on fielding were therefore underpinned by analysis by the AORG who assessed both the lethality of UK weapons systems and the vulnerability of UK armoured vehicles against the Soviet threat. The Army Operational Research Group Memo E13 published in June 1954 compared the lethality of the 20-pdr, as fitted to Centurion and Charioteer, with the 120mm gun being fitted to Conway and Conqueror, looking at both accuracy and effectiveness. Later work went on to investigate the benefits of the 183mm gun. Table 1 gives calculated data for probability of hit (Ph) and the overall probability of kill data (Pk) for British anti-tank guns against Soviet tanks. The Pk data combines the probability of hit data with the probability of significantly damaging the threat tank when a hit is achieved. The data is 'Whitaker Weighted'; this weighting considers the likely distribution of the angles of attack against an enemy tank, hence where the hits are likely to occur – rather than just considering hits on the frontal armour alone.

Table 1: **Probability of Hit and Kill of British Tank Guns against the Soviet Threat Tanks**

	Range >	**1,000 yards**		**2,000 yards**	
Weapon/Round	Target >	JS3	T34/85	JS3	T34/85
183mm HESH	Ph	0.98	0.98	0.59	0.59
	Overall Pk	0.76	0.86	0.46	0.52
120mm APDS	Ph	0.98	0.97	0.71	0.69
	Overall Pk	0.63	0.78	0.42	0.54
120mm HESH	Ph	0.98	0.98	0.38	0.36
	Overall Pk	0.61	0.75	0.23	0.27
20-pdr APDS	Ph	0.95	0.94	0.65	0.63
	Overall Pk	0.45	0.75	0.28	0.50

Of note is the reduced accuracy of the 183mm weapon at the longer range; hence, even though the armour penetration power of the 183mm was greater than the 120mm gun overall it gave limited benefit. Its effectiveness was further reduced by its slow rate of fire. The argument in favour of the 183mm was its ability to penetrate the frontal armour of the JS3. The Pk data for frontal armour attacks only against JS3 are given in Table 2.

Table 2: **Probability of Kill of British Tank Guns against JS3 Frontal Armour**

Weapon/Round	**Overall Pk 1,000 yards**	**Overall Pk 2,000 yards**
183mm HESH	0.67	0.40
120mm APDS	0.52	0.30
120mm HESH	0.55	0.21
20-pdr APDS	0.17	0.11

The other factor considered was the effectiveness of Soviet weapons against British tanks. This is indicated in Table 3 for the 122mm main weapon on JS3 and the 85mm main weapon on T34/85. The calculated data in the table shows the vulnerability of Conway due to its high silhouette and limited armour. Charioteer has a small advantage through having a lower silhouette and hence reduced probability of hit but has very limited protection.

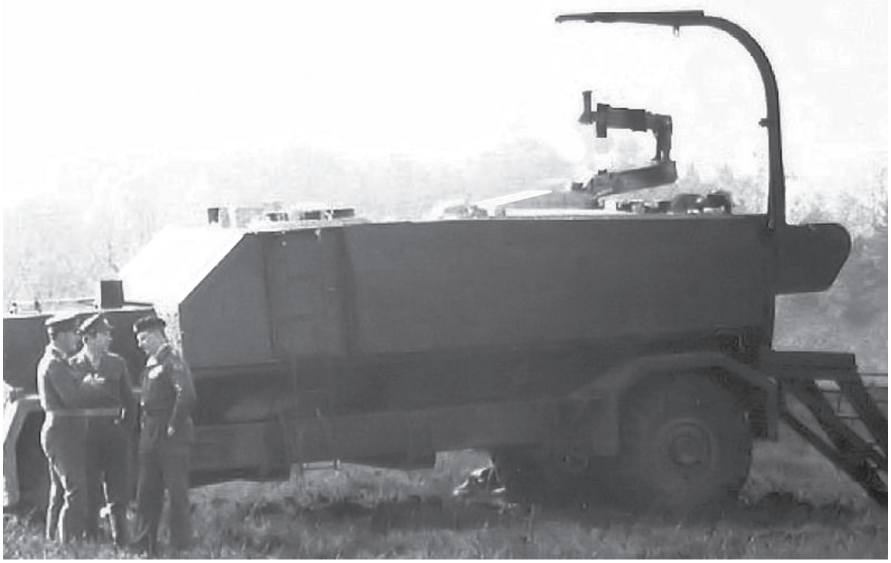
Table 3: **Performance of Soviet Tank Guns against British Tanks**

		Target			
Weapon/Round Range		**Centurion Mk 3**	**Conqueror**	**Conway**	**Charioteer**
122mm APBC 1,000 yards	Ph	0.97	0.98	0.99	0.96
	Overall Pk	0.64	0.50	0.75	0.88
85mm APBC 1,000 yards	Ph	0.96	0.98	0.98	0.95
	Overall Pk	0.32	0.32	0.56	0.86
122mm APBC 2,000 yards	Ph	0.51	0.57	0.59	0.50
	Overall Pk	0.31	0.29	0.43	0.46
85mm APBC 2,000 yards	Ph	0.50	0.55	0.56	0.49
	Overall Pk	0.13	0.17	0.18	0.40

A comparison of Table 1 and Table 3 shows the clear superiority of Centurion over T34/85 and that Conqueror was superior to JS3. T34/85 could overmatch Charioteer at shorter ranges but at longer ranges the greater accuracy of the 20-pdr meant that Charioteer could take on a T34/85 with a high chance of success.

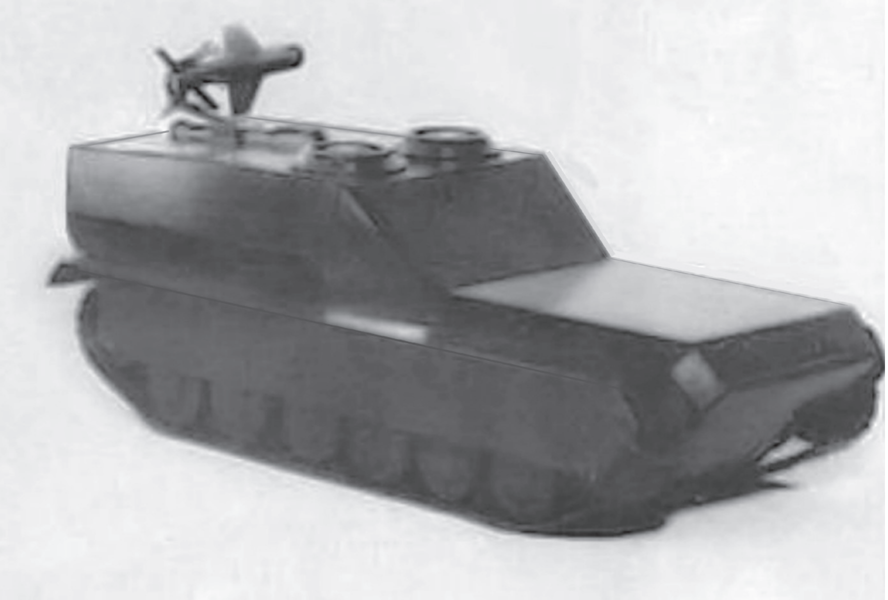
Due to concerns about the reduced accuracy of the larger 183mm L4 gun compared with the 120mm L1 it was decided that the future long-range anti-tank capability should be provided by long-range Anti-Tank Guided Weapons (ATGW). Therefore, at the Royal Armoured Corp Study Conference in November 1952 it was stated that the policy for the future replacement of the Centurion and Conqueror was to have two vehicles; a medium tank with a 105mm gun and a heavy tank destroyer with ATGW. Research into large-calibre anti-tank guns was to continue due to the perceived high risk of ATGW, which at that time were technically immature and lacking operational use. Work to meet the new medium tank requirement started out as the 'Medium Gun Tank Mark 2' project which eventually resulted in the FV4202 Chieftain. The heavy tank destroyer requirement was designated FV4010 for which concepts were developed to inform the build of test rigs. As well as providing the required accuracy at long range, the use of ATGW was seen as a good way to provide higher levels of protection needed within acceptable weight limits as a missile-based launcher system is lighter than a large-calibre gun mounted in a turret.

A 1953 study by the AORG compared the likely effectiveness of the proposed FV4010 and FV215 which was under development at that time. HESH warheads of the same performance were assumed for both the tank round and missile and as the anti-armour performance of HESH is not affected by range, the probability of hit was seen as a key differentiator between the two concepts. Probability of hit by missiles fired by FV4010 was calculated to be 0.85 regardless of range. However, the system was assumed to have a minimum range of 500 yards. FV215 was calculated to have a higher probability of hit at 1,000 yards (0.98) but this fell to 59 at 2,000 yards. Further, these estimates were for static vehicles firing at static targets and the accuracy of FV4010 was assumed to be less impacted if the target was moving. The rate of fire of FV4010 was estimated to be two rounds a minute with FV215 marginally faster at 2.5 rounds per minute. Hence for a long-range anti-tank system FV4010 was assessed to be superior. As it was Centurion based, FV4010 would have a lower level of armour protection than FV215 but had the advantage of being able to engage targets when completely hidden from



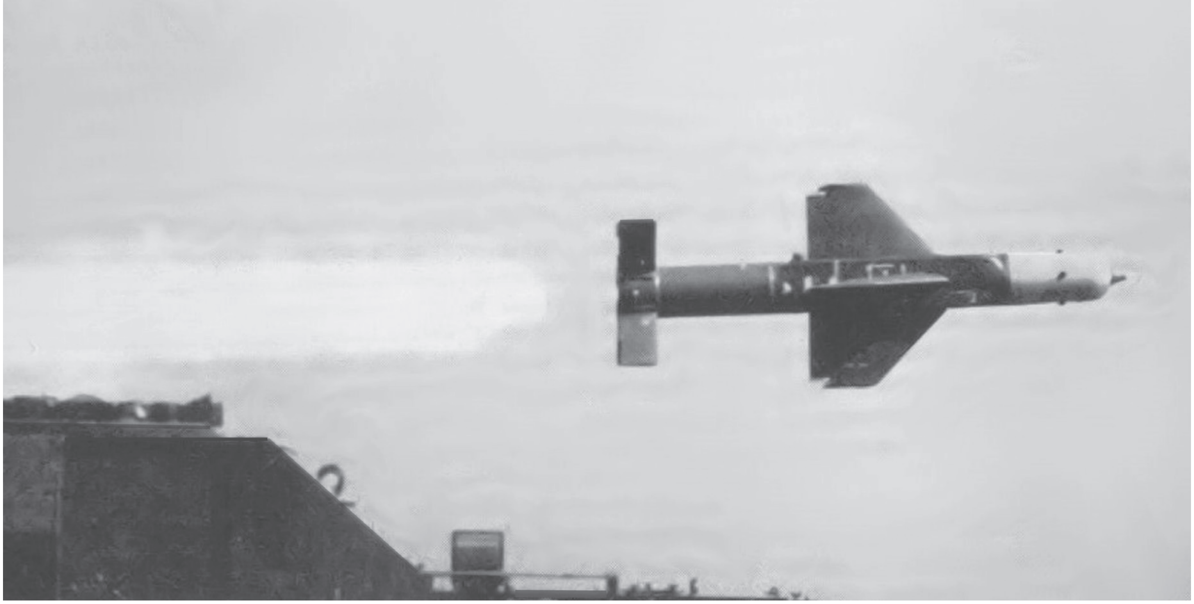
A test rig designed to represent the proposed configuration of the FV4010 heavy tank destroyer. (Crown Copyright MOD) view as the commander could operate the system remotely. The unit production cost of FV4010 was estimated to be £37,000 at 1953 prices compared with £60,000 for FV215, however, it was likely that the ammunition would cost between two and five times as much. This was off-set to some extent by the fact that FV4010 was a lighter vehicle and hence would have a lower fuel consumption.

Chertsey worked closely with the Government Aircraft Factories of Australia who were developing the Malkara missile and also with Fairey Engineering who were developing the Orange William missile; this was a possible alternative or complementary missile to the Malkara with a much greater range of around 5.5km. The initial warhead for Orange William was based on the same 183mm HESH round developed for the L4 gun mounted on FV4005 and intended for FV215. As well as developing concepts for the vehicle to carry and launch the missiles, FVRDE was involved in aspects of the missile launch and guidance systems design including firing circuits, sighting systems and guidance wire dispensing systems. The concept for FV4010 was based around the Centurion hull and running gear and FVRDE built two launch trailers which were designed to represent the configuration of the hull being proposed for FV4010. One trailer was used in trials in Australia in 1956 and the other for trials at Kirkcudbright in 1958. Also in 1958, in support of the development work, the AORG carried out a field study to assess the likely maximum ranges that the missiles would be used at, based on terrain and sight lines; concluding that it would be around 4,000 yards (3,658m). Other studies led to a recommendation that FV4010 should carry at least 20 stowed missiles. The Orange William missile project was cancelled in 1958 as concerns about cost and complexity grew, and along with it FV4010. The Malkara was brought into service as an interim solution pending the development of a new lower-cost solution that was to become Swingfire. Therefore, Chertsey continued work on mounting Malkara on lighter platforms. This included the Hornet, which was based on the Humber 1-ton armoured truck, and equipped parachute brigades. Previously proposals had been made for mounting Orange William missiles on modified Comet hulls to provide an air transportable weapon system weighing around 18 tons. Following the cancellation of FV4010 and the associated Orange William missile system in order to meet the extant requirement for a heavy long-range anti-tank system, the War Office issued a policy statement in 1961. This highlighted a plan to fit Swingfire to



Model of FV4010 proposed as a heavy tank destroyer to armed with the Orange William anti-tank guided missile. (Crown Copyright MOD)

Chieftain under Requirement GSR 1007. Swingfire was developed by Fairey Engineering in conjunction with British Aircraft Corporation (Anti-Tank) Ltd and drew heavily on experience with Orange William. The Swingfire-equipped Chieftains were planned to enter service in 1966/67 but never went ahead; instead Swingfire on FV438 provided the required long-range anti-tank capability.

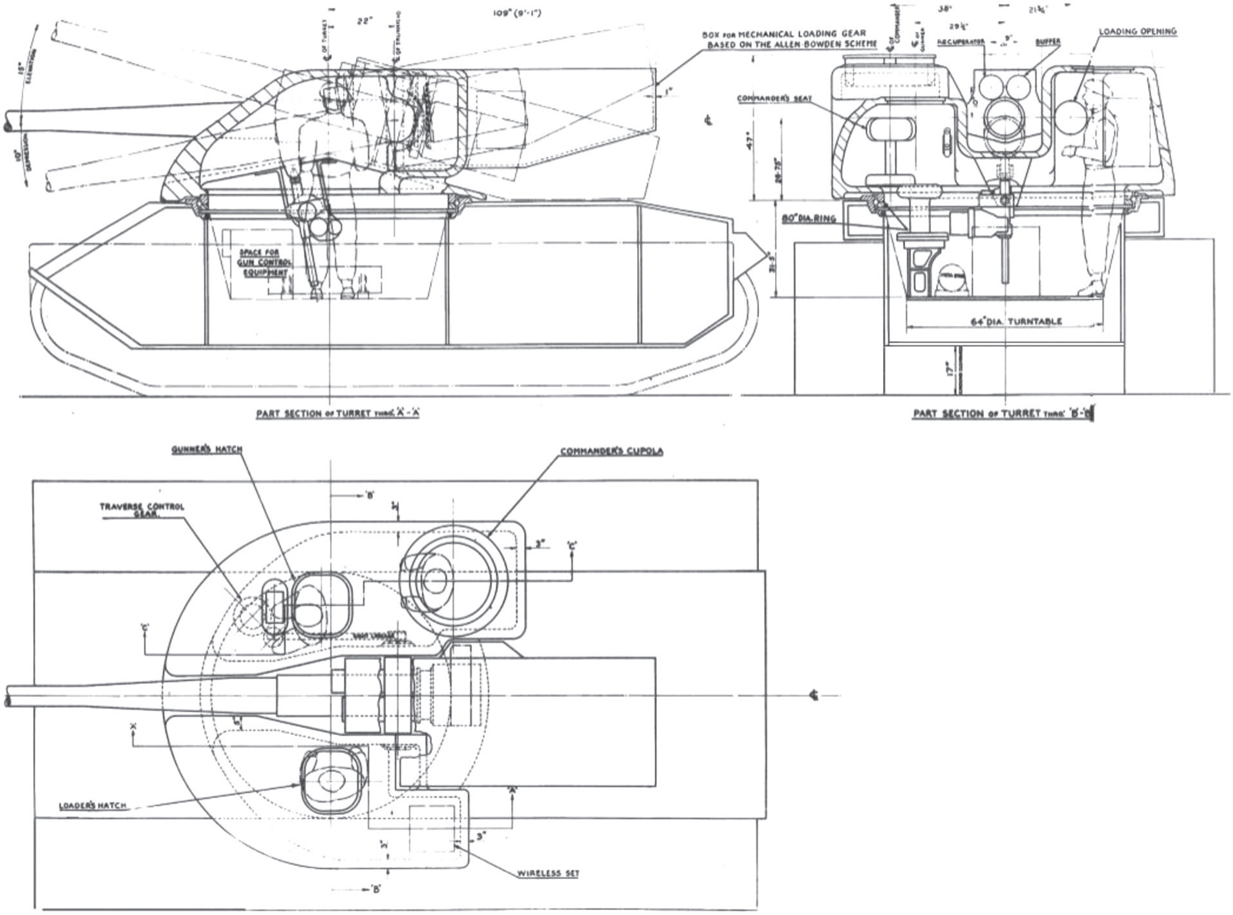


Trial firing of a Malkara missile from the FV4010 hull test rig. (Crown Copyright MOD)

CHIEFTAIN

Although work on the FV215 heavy tank destroyer was cancelled, work went ahead to develop a successor to the Centurion, with the challenge to produce a vehicle that had the firepower and protection of Conqueror but within the constraints of a smaller, lighter platform. The Army defined initial requirements for the new tank (Medium Gun Tank No.2) in 1951. Chertsey started to investigate concepts and by January 1952 had developed a number of turret designs. Early versions used a US 105mm gun but due to the large size of this gun the resulting schemes were considered impracticable. Some work was undertaken on a 'cleft turret' which dispensed with a mantlet and enabled a lower turret. A more extreme attempt to reduce the height of the turret had the gun mounted between two halves of a split turret with the loader one side and the commander and gunner the other side with the trunnions just rear of the turret centre line. An armoured pod over the breach contained a mechanical rammer.

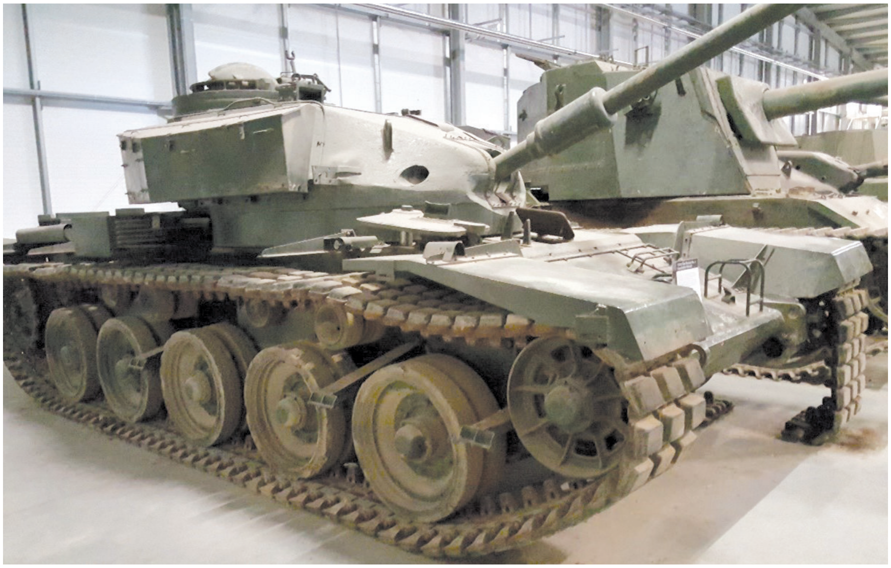
In 1953, following discussions between FVRDE Chertsey and the ARDE, it was decided to investigate the use of liquid propellant guns. However, this approach was soon rejected despite rig work to investigate this technology and installation requirements. In 1954 it was proposed that a concept be developed based on a new design of 105mm gun using bagged charges. The 105mm was considered adequate at the time and the use of bagged charges made loading easier, allowed stowage flexibility and had weight benefits. Also in 1954, a War Office policy document was issued that stated that a replacement for Centurion was required that had mobility at least as good as that vehicle, but a more effective gun and armour. The weapon requirement was then revised following an international agreement that future MBTs should have a gun that could defeat 120mm of Rolled Homogeneous Armour (RHA) at 60 degrees at a range of 2,000 yards. This decision was based on an armour configuration designed to represent postulated future Soviet tanks. Analysis by FVRDE and ARDE, which reported in April 1956, concluded that a 120mm weapon was required. The work on the 105mm gun using bagged charges had shown promise and so the concept was taken forward as the starting point for a new 120mm gun, designated the X23. Meanwhile, Chertsey had looked at a novel approach to minimizing height by use of a prone


15° ELEVATION
10° DEPRESSION
22"
109" (9'-1")
℄ OF TURRET
℄ OF TRUNNION
1"
SPACE FOR GUN CONTROL EQUIPMENT
PART SECTION OF TURRET THRO. 'A'-'A'
BOX FOR MECHANICAL LOADING GEAR BASED ON THE ALLEN-BOWDEN SCHEME
℄ OF COMMANDER
℄ OF GUNNER
38"
29¼"
21¾"
5"
RECUPERATOR
BUFFER
LOADING OPENING
COMMANDER'S SEAT
47"
26·75"
80" DIA. RING
31·5"
64" DIA. TURNTABLE
17"
PART SECTION OF TURRET THRO' 'B'-'B'
GUNNER'S HATCH
COMMANDER'S CUPOLA
TRAVERSE CONTROL GEAR.
'B'
3"
'C'
'A'
LOADER'S HATCH
WIRELESS SET

Split turret concept, one of many schemes considered for the Medium Gun Tank No.2. (Crown Copyright MOD)

posture for the driver. In 1956, to assess if this was feasible from an operational perspective, a test bed, designated FV4202, was built. Based on Centurion components it had a Meteor engine, five road wheels each side and mounted the 105mm bagged charge gun in a cleft turret; it is sometimes referred to as the '40-ton Centurion'. It is believed that at least three examples of the cleft turret were manufactured.

In June 1956 a new concept was produced which included the new 120mm bagged charge gun, (designated the L11), a reclining seat for the driver, a Rolls-Royce 90-degree V-8 engine incorporating an auxiliary engine in the 'V', and an automatic gearbox. The same configuration of Horstmann suspension as Centurion was selected but uprated to carry the higher weight. Torsion bars were rejected as they would have increased the overall height. The weight of the vehicle was estimated to be in the region of 47 tons. At that time it was hoped that with development the



FV4202 in the conservation hangar at the Bovington Tank Museum showing its cleft turret and shortened (five wheel) based Centurion hull. (Author's Collection)

weight could be reduced to 45 tons, which was still considered to be the desired maximum weight for an MBT by the Army. This was backed up by a report from the Army Operational Analysis Research Group, called 'The conventional tank: a study of performance and cost and the selection of optimum weight.' This looked at the impact of a wide range of design considerations on weight including protection levels, mobility factors, number of stowed rounds and classification of road bridges in Germany. It also carried out analysis of the relationship between weight and cost. The report concluded that the trend in increased weight to allow increases in armour was not sustainable and recommended 45 tons as the optimum target weight for a tank. Leyland Motors was appointed as the main design contractor and some detailed design work started. It was then decided that the UK 120mm gun and US T208E9 90mm smoothbore should be interchangeable in both the new UK tank, now designated the FV4201, and the T95 being developed by the US. This then led to a decision to explore the use of a common turret for the UK and US tanks.[3] The common gun and subsequent common turret requirements resulted in a significant amount of redesign activity adding delays to the programme. At a UK/US bilateral meeting in 1958 it was reported that the FV4201 turret could be fitted to the T95 hull but changes would be required to fit the T95 turret to the FV4201 hull. However, by that time the US was working on the XM60 and soon abandoned the T95 with its complex hull with adjustable suspension. The much simpler XM60 entered service as the M60. There was an initial assessment of whether the XM60 could be fitted with the FV4201 turret which concluded it could be feasible, but the idea was not taken forward.

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[3] In the USA a prototype T95 was built with a 105mm gun. The turret with a 120mm gun was referred to as the T96 turret and a proposed version of the T95 with the T96 turret referred to as the T95E6.

The initial designs for the 'Medium Gun Tank Mark 2' had a welded construction for the hull front but later a cast solution was selected in order to provide the toe plate and well-sloped hull glacis with the required levels of robustness and protection. It has been suggested that the design was inspired by the castings on a Soviet JS2 tank which had been discovered under the wreckage of a collapsed building in Berlin when the area it was in was taken over as part of the British Sector. An early scale model of the Medium Gun Tank shows an upside down 'V' shape for the joint between hull glacis and the toe plate which is very similar to the hull front configuration of the Soviet JS3. The same model has a turret glacis shaped like that of Conqueror rather than the final cleft turret solution.

In November 1957 the 3rd version of the operational requirements document was issued and this revised the gun elevation and depression limits which increased significantly from +15 degrees and -7 degrees to +20 degrees and -10 degrees. To accommodate this change, the height, and hence weight, of the turret had to be increased. Further changes to requirements included an increase in protection and the fitting of infrared night-fighting equipment. Towards the end of 1957 the NATO policy to use multi-fuel engines was agreed leading to a decision in January 1958 to fit an opposed-piston multi-fuel engine. The use of this engine required a redesign of the engine compartment – which added another ton to the overall weight. At this stage the estimated weight of the vehicle was 50 tons but it was thought that a revision of the armour scheme and other changes could bring the weight down to 48 tons. A proposal was also made for a lightened engine to help bring the weight down to the target 45 tons but this was not taken forward. The changes of requirements and policy meant that the project was now falling well behind schedule and the situation had not been helped by the fact that Leyland Motors had been working on the Centurion Mark 7 at the same time. In order to help the situation, Vickers-Armstrong was appointed as the second main contractor in August 1958 to take over responsibility for the detailed design of the turret. A mock-up was built and an acceptance meeting held in March 1959. The first automotive rig, P1, had its engine installed in September 1959 and this was followed by another automotive rig, P2, in April 1960. In addition to six prototypes built for development trials (P1 to P6) a further six were ordered in June 1959 for user trials (W1 to W6), along with two vehicles (G1 and G2) specifically for gunnery trials.

The prototypes, with initial delivery dates, were:

P1	January 1960	Automotive test rig with dummy turret
P2	April 1960	Automotive test rig with dummy turret
P3	August 1960	Gun and gire control development rig, including IR equipment
P4	July 1961	Firing trials development vehicle
P5	April 1962	Development trials vehicle
P6	Nov 1962	Development trials vehicle (on completion of trials was put on a plinth at Chertsey)
W1	March 1961	Initially at Bovington and then reworked for user trials in BAOR
W2	April 1961	Fitted with a 'Windsor' turret and sent to Bovington for driver trials.[4] This vehicle was the first to be modified with Centurion-type road wheels to give an increase in ground clearance
W3	April 1961	Initially sent to Kirkcudbright and then Lulworth for gunnery trials before rework for user trials in BAOR
W4	Dec 1961	FVRDE/user trials at Bovington
W5	February 1962	Bovington
W6	April 1962	BAOR Germany
G1	January 1962	Lulworth for gunnery trials
G2	Nov 1962	BAOR Germany

In the meantime, development of the X23 120mm gun was continuing with the first prototype completed in January 1959. This was followed by 11 further prototypes with the first gun built specifically for vehicle installation delivered in July 1959.

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[4] The Windsor turret was a circular dummy turret without a gun to provide a representative turret weight for automotive trials.

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Chieftain Mark 3 being used for training. (The Tank Museum, Bovington)

Chieftain Prototype P6 on the plinth by the main entrance at Chertsey where it was the 'gate guardian' for many years. (Crown Copyright MOD)

Much of the build of the initial prototypes was carried out at FVRDE where reworking to keep them up to the latest build standard was also undertaken, especially as automotive components were developed and improved.

Following initial user trials larger road wheels, of the type fitted to Centurion, were fitted to increase ground clearance from 431mm to 560mm. The modification also required the rear drive sprocket and front idler to be raised. With this change the prototypes now weighed 49.5 tons and the weight further increased when heavier tracks were fitted to meet the German Government requirement to operate with rubber track pads. A further weight increase came with the introduction of the Nuclear, Biological and Chemical (NBC) collective protection system. By this time the estimated weight for production vehicles was 53 tons, which was considered too heavy. Some weight reduction was achieved by a reduction in the arc over which the maximum frontal armour protection was provided, removing armour from the searchlight and the army agreeing to reduce HESH round stowage by six rounds. The increase in weight had led to gearbox and running gear reliability issues and the engine being underpowered, hence further redesign and development was required. Changes to the engine, strengthening the gearbox and fitting larger air filters, along with lengthening of the hull to incorporate these changes, added further weight. Other more minor design changes involved the exhaust configuration, the location of the infantry telephone and the deletion of a towing pintle at the centre of the heel plate.

The first development (unmanned) firing trial, on W3, was carried out in May 1961 following which some modifications were made in order to prepare the vehicle for manned firing trials by the user. Following jump and accuracy trials the following January, gunnery trials continued throughout 1962 including work to improve the ranging machine gun and trials with the infrared equipment. The trials were largely successful with the only major issues being experienced with the commander's cupola and contra-rotating system, which were modified for the Mark 1 vehicles.

Chieftain made its first public appearance in October 1961 with the hull front and the mantlet area masked.

Despite delays and 'weight creep' due to the changes in requirement, development continued and what became called the Chieftain, designated FV4201, was formally accepted for service on 1 May 1963. Initially 40 Mark 1 vehicles were built for troop trials and training. The first of the full production vehicles (Mark 2) was delivered to the 11th Hussars in November 1966 with ten vehicles a month being delivered from January 1967. The Mark 2 had the revised automotives and running gear, an NBC pack, a contra-rotating commander's cupola with improved all-round vision and a single piece hatch, revised stowage and a Browning RMG in place of the M85 gun. It weighed 55 tons.

The basic layout of Chieftain was similar to that of Centurion with the driver at the front, a central turret with a three-man crew and power pack and drive at the rear. The automotive performance was similar to Centurion but Chieftain provided significant advances in terms of firepower, with a 120mm gun, and protection with its well-shaped cast hull and turret front. The rest of the turret and most of the hull were fabricated from welded steel armour plate. Full technical data for Chieftain is given in Appendix C.

Despite the increase in weight, testament to the success of the Chieftain design is the fact that the production Chieftains still weighed 10 tons less than the Conqueror yet had 388mm frontal armour compared with 258mm on the Conqueror. It also had greater gun depression, which had been a shortcoming with Conqueror. When fielded it was the best protected in-service NATO tank and remained so until 1980. The areal density of the armour, 3 tonnes per square metre, has never been bettered.

The one significant area of weakness with the Chieftain was its power pack. The unusual two-stroke opposed L60 piston engine, selected to

Chieftain Mark 3 with the hatches fully closed down. (The Tank Museum, Bovington)

meet the multi-fuel requirement, was underpowered in light of the weight growth of the vehicle. When first brought into service it proved to be very unreliable – leading to the joke 'Chieftain is the best tank in the world provided it breaks down in a good fire position'. Development of the engine was well under way by 1958 and a single cylinder test bed was running by December of that year. In parallel, Self-Changing Gears of Coventry started development of a semi-automatic 'hot-shift' transmission based on the TN10 developed for the FV300. Designated TN12 the first transmission began dynamometer testing in March 1959 and, following some modifications, completed type testing by September.

A number of issues were encountered with the prototype engines including damage due to vibration and hydraulic and coolant leaks which had to be addressed. Other improvements implemented during engine development covered the cooling system, lubrication, exhaust smoke reduction and changes to the fuel injection system to increase power. Reliability issues continued to be experienced during vehicle development and user trials and on into service life. Therefore, significant efforts were made to address the issues with an ongoing programme aimed to both increase the power and improve reliability. There were particular issues with aspects of the pistons and piston ring design which had to be resolved with the result that the final versions of the engine were significantly more reliable. Ironically the requirement for a multi-fuel capability that drove the selection of what proved to be a challenging engine configuration was never really needed. One requirement for the power pack was that the engine, gearbox and cooling system should be combined to facilitate rapid removal for repair; this did at least mean that replacing the pack was a relatively straightforward task and minimized vehicle down time. The L60 development programme included:

Year	Activity
1958	May: L60 specification agreed; August: development contract placed
1959	1st prototype engine run; cooling and lubrication issues highlighted
1962	Chieftain user trials in BAOR with Mk 2 engine – user raised issues of poor reliability and lack of power
1964	Mk 4 engine commenced running, but cylinder scuffing an issue on type testing
1965	Production of the Mk 4 engine started
1966	Symposium held to identify potential alternatives to L60; none found
1966/67	Rissole 1 and Rissole 2 trials of design changes to reduce fuel consumption and increase fan belt life
1967	Scotch Mist programme started, aimed to increase power to 650bhp and achieve 3,000 miles' life. Resulted in new liner materials and modifications to the sump, fan belts and air filters
1968	Fleetfoot programme started, aimed to increase power to 750bhp. Resulted in more efficient fans, improved airflow into engine and changes to pistons and rings. Achieved 720bhp
1969	Mk 5a engine introduced with changes from Scotch Mist programme
1970	Mk 6a engine introduced with new low loss air filter and other modifications to oil pipes and tank
1971	Dryfoot trial. Trials in Yuma desert to support overseas sales. The three engines used achieved 2,049, 1,708 and 1,617 miles
1971	High Noon programme started, aimed to achieve 4,000-mile life at 720bhp
1971	Mk 7a engine introduced with changes from Fleetfoot programme
1972	Dark Morn programme started, aimed to ensure that the production version of the Mk 7 engine achieved the same reliability as achieved by the Fleetfoot engines
1973	December, Mk 8A engine introduced, changes to liner, piston crowns and scavenge blower
1974	New liner introduced. Mk 8 engine achieved 2,800 miles in a user trial
1975	Bright Morn trials. Trials of reworked engines incorporating Dark Morn improvements
1976	Sundance Trial. Yuma desert trials of two vehicles to confirm performance and reliability
1977	Mk 9a engine introduced with further changes to liners, piston crowns and rings
1977	Mk 10a engine introduced, Mk 9 engine fitted with revised blower for overseas sales
1979	Mk 11a and 12a engines introduced with revisions to 'O' ring fit
1979	Exercise tunnel light to monitor the reliability of Mk 11a engines at BAOR and BATUS Canada[5]
1980	Mk 13 engine introduced

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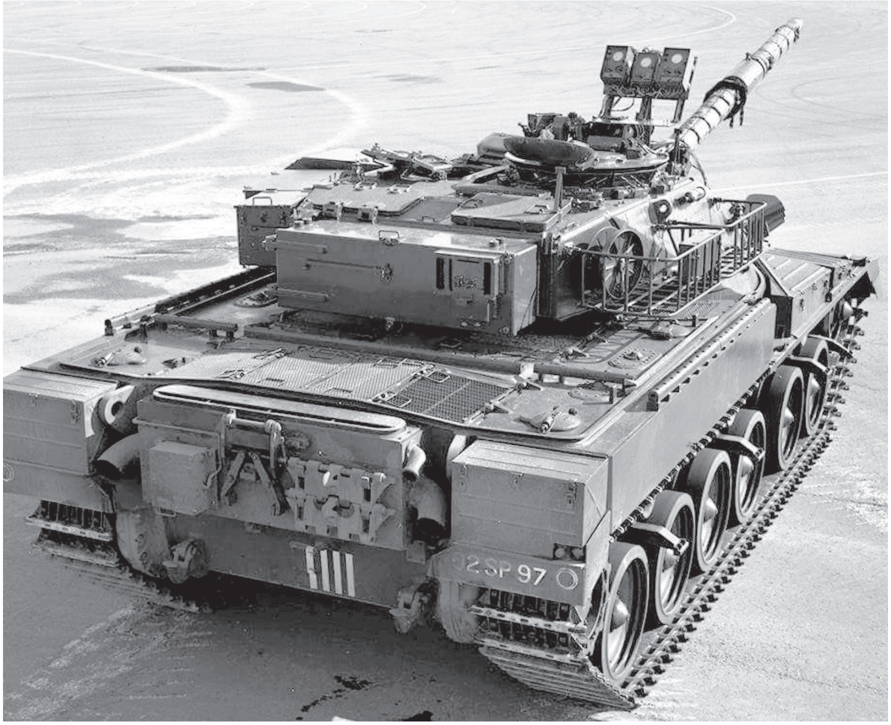
[5] BATUS is the British Army Training Unit Suffield.

By the time the 'Sundance' design changes had been developed and implemented the reliability of the engine had significantly improved. The final phase of the Sundance solution development was Sundance Phase 3 for which Leyland delivered two engines to the new-build standard, SD22 and SD23, which soon achieved over 4,000 miles without failure. Some minor modifications were identified and these were incorporated on engine SD24 which exceeded 4,000 miles by October 1977. A requirement was for REME workshops to be able to build engines to the new standard using, where possible, engine blocks and other non-Sundance components from existing engines. The first reworked engines, using new blocks but recycled components, suffered unrelated failures, but by January 1979 engine SD29, which had been assembled at 23 Base Workshop, achieved 4,087 miles and after inspection reached 5,380 miles without failure. Based on the success of this, and other engines reworked by REME, approval was given to start reworking engines, but using new blocks, to what was designated the Mark 11A build standard. In January 1979 development was started on what was called the 'No "O" Ring Tight Liner' or NRTL solution which it was hoped could enable old blocks to be used for reworked engines. Four trials engines and one spare were built, four by Leyland and the other by 23 Base Workshop. These successfully achieved 4,000 miles and one, fitted to an in-service Chieftain, achieved over 6,500 miles without failure. The successful testing resulted in the introduction of the Mark 13A engine which recycled selected used engine blocks. By 1982 all BAOR Chieftains had been fitted with either the Mark 11A or Mark 13A engine.

The real worth of the Chieftain was demonstrated by the desire of Israel to buy it. They had considered the German Leopard 1 tank which was allegedly described as a 'good agricultural tractor' in comparison. In support of the potential sale, under a programme called HOTSHOT 1, vehicles undertook hot weather trials in Aden between June 1966 and September 1966. Then under HOTSHOT 2 they went to Israel for firing trials. Chieftain had been developed to counter the threat from Soviet tanks and Israel was keen to purchase a new state-of-the-art vehicle to counter the same vehicles, which they knew would quickly appear in the inventory of surrounding Arab nations. The purchase was blocked by the Wilson Government but Israel used the knowledge gained from operating Chieftain to develop the Merkava tank instead. As well as

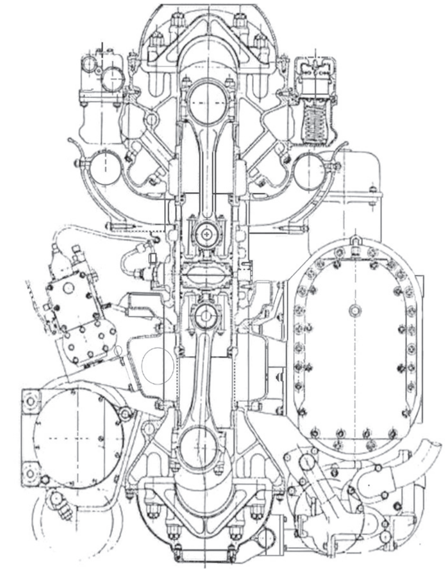


Chieftain Mark 4 fitted with instrumentation for trials in the Yuma Desert in the USA. (Crown Copyright MOD)

Israel, Chieftain was assessed by the Netherlands, with the potential sale supported by Exercise CRACKLE, which ran from November 1967 to July 1968, and by Switzerland supported by Exercise Royal Chief, which ran from August 1971 to March 1972. Although no European nation procured the vehicle, Chieftains were sold to a number of Middle East countries: Iran (707 Mark 5P), Kuwait (150 Mark 5K) and Oman (12 Mark 7 and 15 Mark 13).

Chieftain was the subject of ongoing updates and upgrades, some of which were given impetus by the potential sale to Israel. A new NBC pack was developed and further improvements were made to the gun and fire control equipment as it moved from a ranging machine gun to a laser rangefinder-based system. The Tank Laser Sight (TLS) started to be fielded in 1973 on later Mark 5 production vehicles which were fitted with the TLS No.1 Mark 1. By May 1974 production of TLS1 was complete but an improved version, TLS No.2 Mark 2 had been developed and conversion kits were going into production. The new No.6 NBC filtration pack was first fitted to Mark

BELOW
Cross section of the L60 engine showing its vertical opposed pistons. (Crown Copyright MOD)



3/3 vehicles with a modified version, the No.6 Mark 2, being fitted to Mark 5 vehicles. The Mark 5, which started to be delivered in 1971, could also be fitted with an infrared illumination detection system.

One of the most significant upgrades to Chieftain was the Improved Fire Control System (IFCS) which was first fitted to the Mark 8, but developed to be retrofitted to any version from Mark 2 onwards. Development of IFCS started in 1971 following the issue of a General Staff Requirement (GSR) 3540. IFCS introduced the Muzzle Reference System, which had been successfully demonstrated in user trials as reported in February 1971, and a new digital fire control system. The Muzzle Reference System used a mirror mounted on the end of the barrel to detect and compensate for barrel bend. The full IFCS solution was subjected to user trials at the Armour Trials and Development Unit (ATDU) starting in April 1975 and running through to the following year. The system and the new No.21 Cupola were fitted to Chieftain 00 FD 95 which was called 'Pandora' by the ATDU staff. It was designed to increase hit probability against static and moving targets and to reduce engagement times. IFCS consisted of four main sub-systems:

1. The Data Handling Sub-System, which included a digital computer and interface unit, the commander's control unit and the commander's and gunner's firing handles.
2. Sighting Sub-System, based on the Barr and Stroud Tank Laser Sight No.2.
3. Sensor Sub-System, with sensors for cross- and headwind, air density, trunnion tilt, elevation and azimuth and a rounds fired counter.
4. Gun Control Equipment (GCE), an updated version of the GCE No.7, designated the GCE No.10 giving improved turret traverse speed and aiming control.

The gunner's and commander's firing handles brought together the armament selection, ammunition selection, laser ranging, autolay demand and firing trigger onto one unit and introduced thumb controls for accurate weapon control on the move. Key to the operation of IFCS was automatic calculation of the gun aim point relative to the target location as viewed through the main sight – the so-called 'off-set'.

This automatically compensated for factors such as target motions, range, crosswinds, etc., and provided faster and more accurate gun laying than traditional graticule-based solutions.

The final major upgrades to the Chieftain which significantly enhanced its capability were the fitting of the Thermal Observation and Gunnery Sight (TOGS) and additional turret armour.

TOGS was based on the Thermal Imager Common Module (TICM). The Royal Signals Research Establishment at Malvern had been developing thermal imaging technology for a number of years and a major breakthrough was made with the 'TED' detector, named after its inventor, Ted Elliott. The TED detector was incorporated into the TICM system which had a significantly better performance than contemporary thermal imagers. Work on integrating thermal sights into MBTs had started at Chertsey as part of development work for MBT80 and continued after that project was cancelled. By 1982 thermal imaging systems had been fitted to four Chieftains for trials and based on the success of these TOGS was brought into service; hence Chieftain was the first operational tank to have a fully integrated thermal sight giving an effective night-fighting capability. The TOGS unit replaced the searchlight and was mounted in the same location. Although lower in profile it was longer, due to the cooling engine behind the imager, and so additional mounting pads were welded to the turret. Due to significant dimensional variability in the large castings of the Chieftain turret, locating the mounting pads was, at times, a difficult task, even when using a jig that had been designed for tolerances of up to 50mm. Unlike the searchlight, TOGS was provided with ballistic protection in the form of 18mm of RHA. Internally the fitting of TOGS required 16 new boxes and 30 new cables. Additional modifications were required to the ammunition stowage and radio equipment.

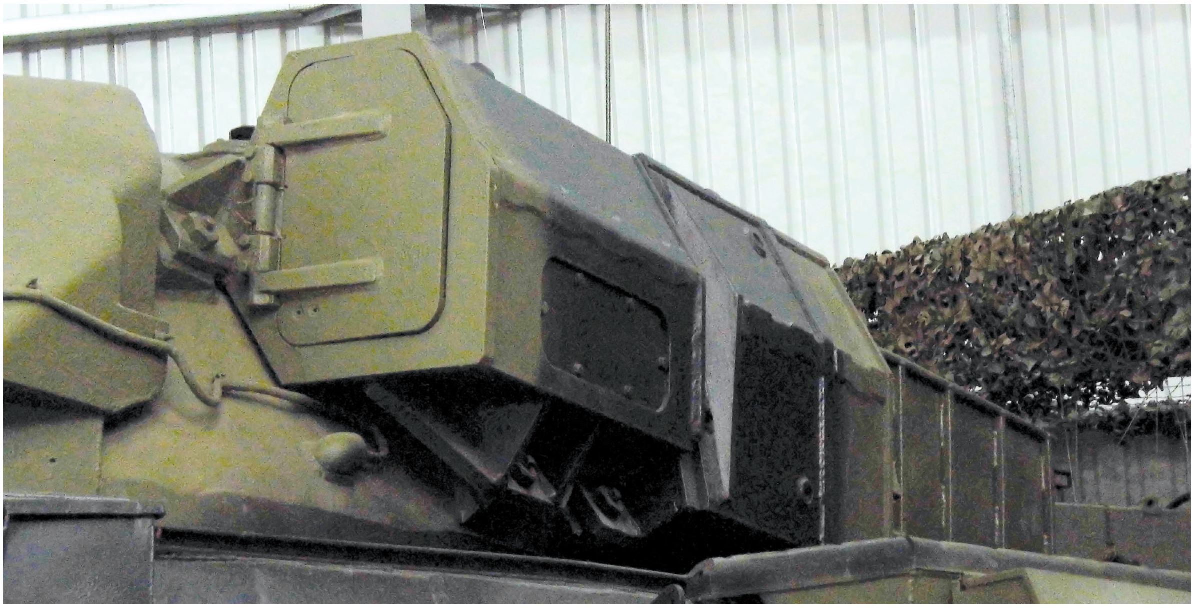
The decision to fit additional armour to the turret followed information on the performance on Chieftain in the Iran–Iraq War. A concept for an up-armouring solution was designed and tested by the Military Vehicles and Engineering Establishment (MVEE) over a period from May 1982 to September 1983, before full development was undertaken by ROF Leeds. The new armour fit was named Stillbrew after Col. Still (from the Army Operational Requirements branch) and John Brewer (a senior member of Chertsey staff).

Fitting the additional armour and TOGS required the relocation of smoke dischargers, turret lifting eyes and a fire extinguisher along with minor modifications to the engine decks. The additional weight of the modifications was 450kg for TOGS and 2,000kg for the Stillbrew armour. The modification and installation work was carried out at 23 Base Workshop and 38 Central Workshop.

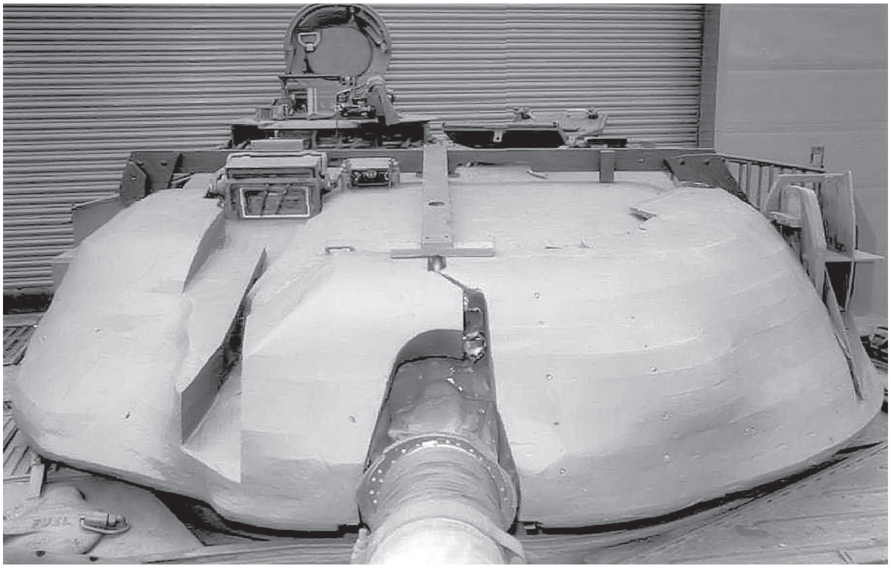
Related to the work to fit TOGS was the development of a new tank laser sight which had a CO2 laser, rather than the earlier ruby or neodymium-YAG (Yttrium, Aluminium, Garnet) lasers, operating at a wavelength compatible with TOGS and providing improvements in performance.

There was further work to improve IFCS, and the Improved Computer Sighting System (ICSS) was developed. This used an independently stabilized aiming mark system, referred to as 'Independent Aiming Mark' (IAM), to improve target tracking and the probability of hit against so-called non-cooperative moving targets.

As discussed, Chieftain was subject to ongoing upgrades and a number of different build standards were fielded, some were new-build vehicles and some modifications of earlier vehicles. As with Centurion, various 'Mark' designations were allocated to different build standards and, like Centurion, the system was somewhat complicated. The main different Marks of Chieftain were:



The 'TOGS' barbette as fitted to Chieftain Marks 10 and 11, with the armoured door over the Thermal Imager lens closed. (Author's Collection)



A wooden mock-up of the original Chertsey Concept for the up-armouring of Chieftain which formed the basis of the 'Stillbrew' amour fit. (Crown Copyright MOD)

- The Mark 1 (1965) first batch of 40 pre-production vehicles used for training only. Some design changes implemented on later Marks were retrofitted to the Mark 1 including new cupolas, revised exhausts and IR driving headlights;
- The Mark 2 (1967) was fitted with a more powerful 650hp engine, a commander's machine gun and updated sighting equipment;
- The Mark 3 (1969) was fitted with the Mark 1 NBC pack, modified No.15 Mark 2 commander's cupola, improved suspension, the improved No.4 Mark 5A L60 engine and an improved No.4 Mark 10a auxiliary engine which provided improved hydraulic main engine starting;
- The Mark 3/1 had improved commander's and gunner's sights, the improved No.7 Mark 5 gun control system and Clansman radio;
- The Mark 3/2 had improved electrical equipment and air cleaners;
- The Mark 3/3 saw the introduction of the tank laser sight and the improved No.6 Mark 1 NBC pack which increased the weight by 300kg;
- The Mark 3/P was an export version for Iran. It was the same as the 3/3 but did not have the tank laser sight;
- The Mark 4 was aimed primarily at overseas sales with increased fuel capacity and various improvements to support desert operations. It did not enter service but two prototypes were manufactured and tested in the Yuma Desert in the USA;

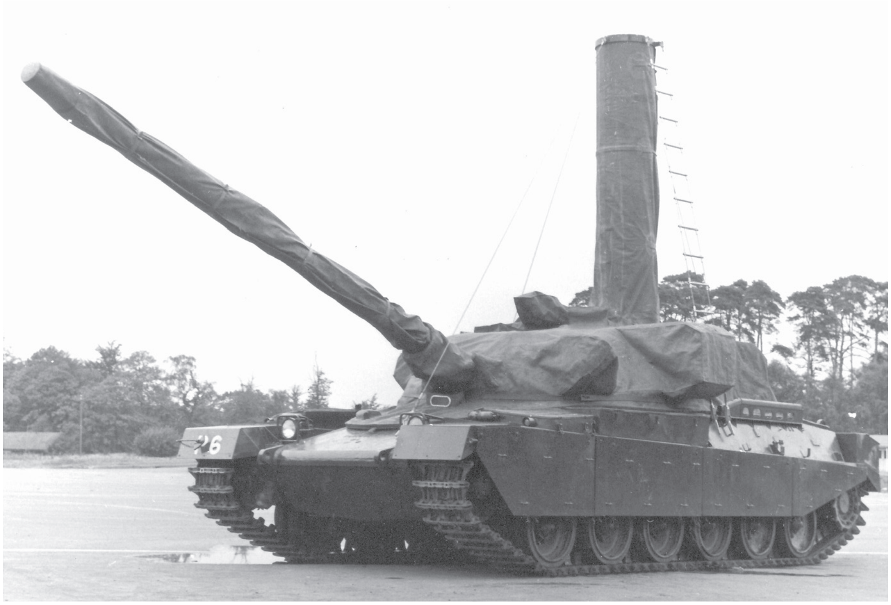
- The Mark 5 (1970) was based on the 3/3 version but with the L60 Mark 7a engine with power increased to 720hp. It also had an improved commander's cupola, gunner's telescope and NBC pack, a revised thermal sleeve, and provision for an infrared sensor, to detect if the vehicle is being illuminated by a threat. The weight was 400kg more than the Mark 3;
- The Mark 5P was an export version for Iran. This had a different radio fit and the L60 Mark 8a, providing 750hp, and an improved TN12 Mark 4 gearbox. It also had an increased fuel capacity. As discussed later it was referred to as 4030 Phase 1;
- The Mark 5-3P was a version of the Mark 5P with increased mine protection and weighing 1 tonne more;
- The Mark 5/2K was an export version for Kuwait. This had an improved gunner's sight and the TN12 Mark 7 transmission;
- The Mark 6 (1979) was an upgraded Mark 2 rebuilt to Mark 5 standards;
- The Mark 7 was a Mark 3 rebuilt to Mark 5 standards;
- The Mark 8 was a Mark 3/3 rebuilt to Mark 5 standards;
- The Mark 9 was a Mark 6 fitted with IFCS and revised ammunition stowage;
- The Mark 10 (1985) was the Mark 6 or Mark 7 fitted with IFCS and Stillbrew;
- The Mark 11 (1988–90) was the Mark 8 fitted with IFCS, Stillbrew, No.11 NBC system, and TOGS;
- The Mark 12 was a production standard version as described in the MVEE publication British Military Vehicles 1981. It was basically a Mark 5 with IFCS and an updated cupola and gunner's telescope and the Mark 11a engine;
- The Mark 13 was a production standard vehicle defined in DGFVE (Director General Fighting Vehicle and Equipment) Specification 324, very similar to the Mark 12 but with an IR illumination detector fitted as standard;
- No information has been found regarding the Mark 14;
- The Mark 15 was a Mark 5-3P configured for sales to Oman (called the Qayid Al Ardh) and equipped with Racal Jaguar radios. It was not fitted with IFCS but was equipped with the Vickers L22 gunner's sight which incorporated a laser rangefinder.

For Mark 5, 6, 7 and 8 there were sub-marks depending on the status of its fire control system upgrade as follows:

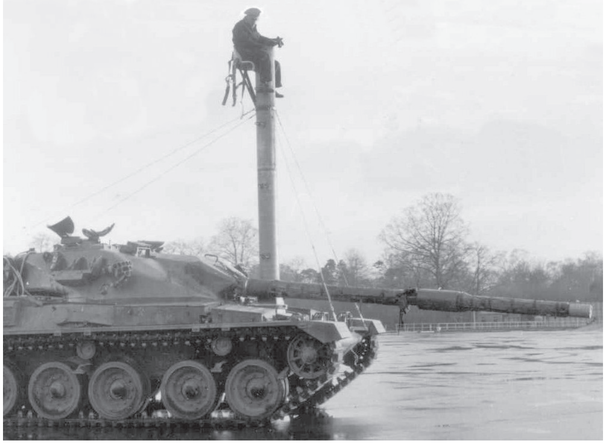
- 5/1, 6/1, 7/1 and 8/1: TLS fitted;
- 5/2, 6/2, 7/2 and 8/2: TLS and Muzzle Reference System (MRS) fitted;
- 5/3, 6/3, 7/3 and 8/3: TLS, MRS and cupola modifications fitted;
- 5/4, 6/4, 7/3 and 8/3: New site graticule and stowage changes for Fin Stabilised Armour Piercing Discarding Sabot (FSAPDS) ammunition.

From the late 1970s vehicles were retrofitted with Clansman radios. Vehicles modified with the Clansman radio harness had a '(C)' after their mark number.

Many of the upgrades of earlier Marks to fit the latest automotives, improved sights and gun and fire control were undertaken under the 'Totem Pole' conversion programme. The programme had 3 elements, called X (mainly covering sighting system modifications), Y (covering L60, air cleaners, parking brakes, fitting of the TLS, etc.) and Z (L60 modifications, new NBC pack, new gun clamp, changes to the electrical system, fitting Clansman radios etc.). The conversions were undertaken mainly at Base and UK Command Workshops.



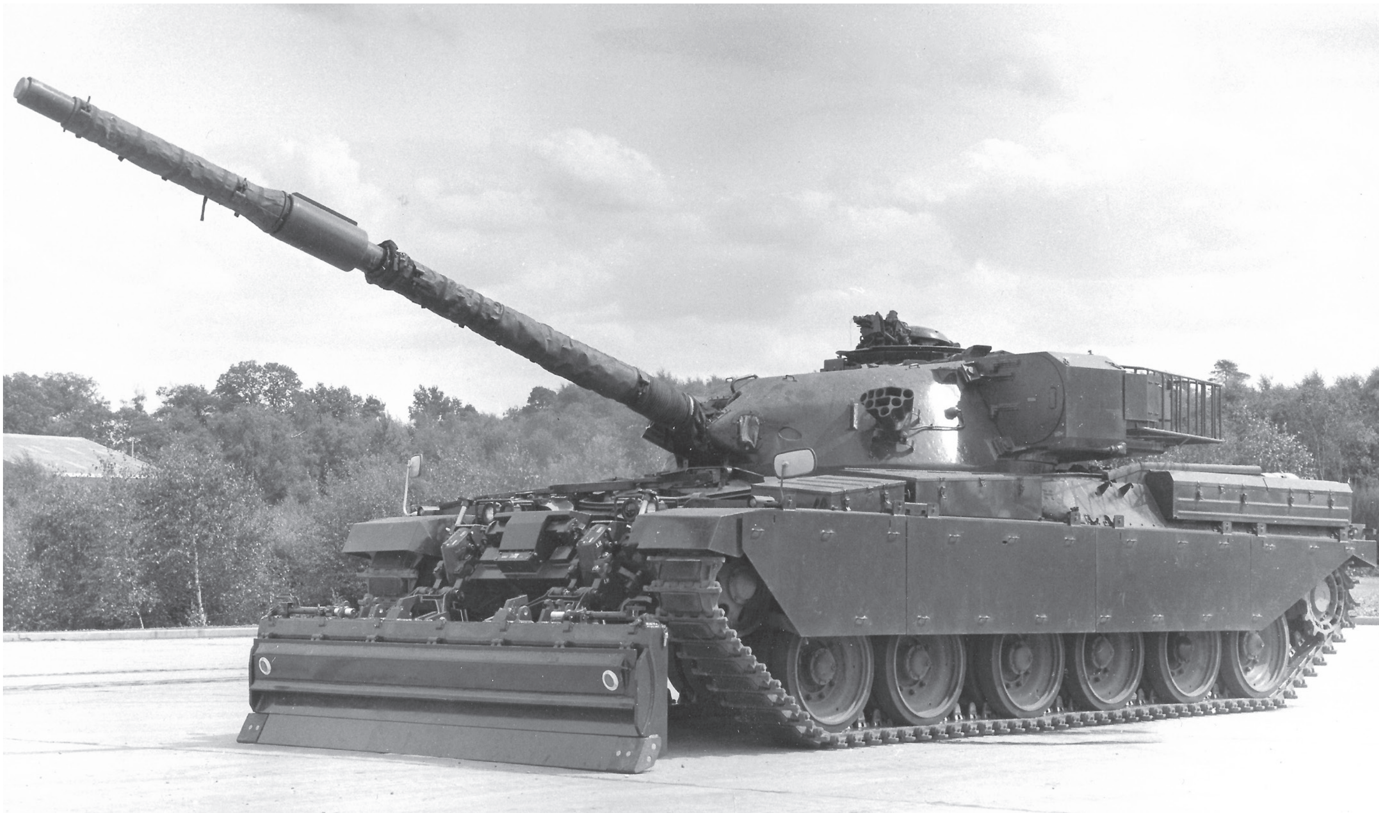
Prototype snorkelling system fitted to Chieftain prototype P6 pictured on the 'slip pan' at the Longcross test track facility. (Crown Copyright MOD)

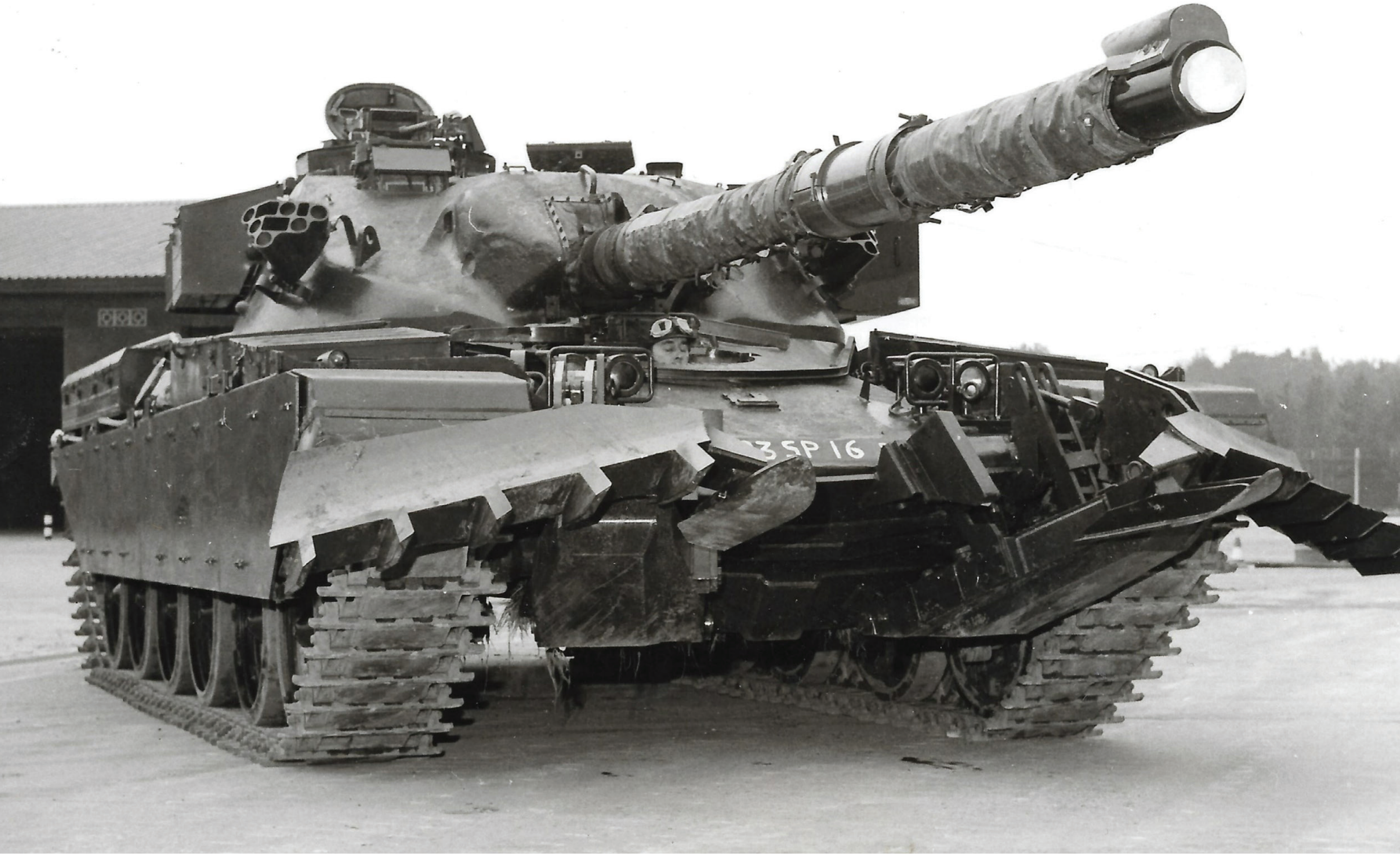


The 'Monkey up a stick' prototype lightweight snorkelling system. (Crown Copyright MOD)

Chieftain also formed the basis of the FV4030 Phase 2 or Shir 1 tank described later in this book. The 4030 Phase 2 project initiated a study into a new engine for Chieftain. The engine selected was the Rolls-Royce CV12 TCE 800hp; one of a family of V engines being developed by Rolls-Royce Motors at that time and based on two V-6 units joined together. At 800hp this had a lower power than a version being developed for 4030 Phases 2 and 3 but more than the 750hp of the latest versions of L60. A trials installation was made in a standard Chieftain in order to gain experience of running the engine and test the impact of the increased power on the gearbox and running gear. The original trials plan for the re-engined vehicle required 3,000 miles with a mix of road and cross-country running. The 3,000 miles were achieved with no major incidents and the trial extended to 4,000 miles. The vehicle undertook 2,013 miles' road running, 1,987 miles' cross country and 152½ hours' idling. The trials report stated that, 'Performance checks during the trial showed it to be as good as the L60 engine version in all respects and measurably better in most.' In 1973 a study was undertaken into installing the same engine in a

Chieftain Mark 5 fitted with the appliqué dozer blade kit. (Crown Copyright MOD)





Chieftain Mark 9 fitted with the track-width mine plough. (Crown Copyright MOD)

Chieftain ARV. As work to replace Chieftain was under way at the time, the British Army did not adopt the new engine, although ROF Leeds offered Chieftain with the 800hp engine as an export version.

For very deep wading a snorkelling system was developed for Chieftain as the vehicle weight was too high for a practical flotation system. The system sealed the vehicle and had a large snorkel tube through which the engine breathing and cooling air was drawn.

A lightweight snorkelling system that required less stowage and would have been quicker to install was also tested. This had a tube mounted over the driver's hatch. At the top of the tube a somewhat precarious seat was provided for a driver. This rather unconventional system was referred to as the 'Monkey up a stick'.

Two appliqué kits were developed and fielded for fitting to the Chieftain gun tanks; these were the Chieftain Dozer Kit and the Track Width Mine Plough.

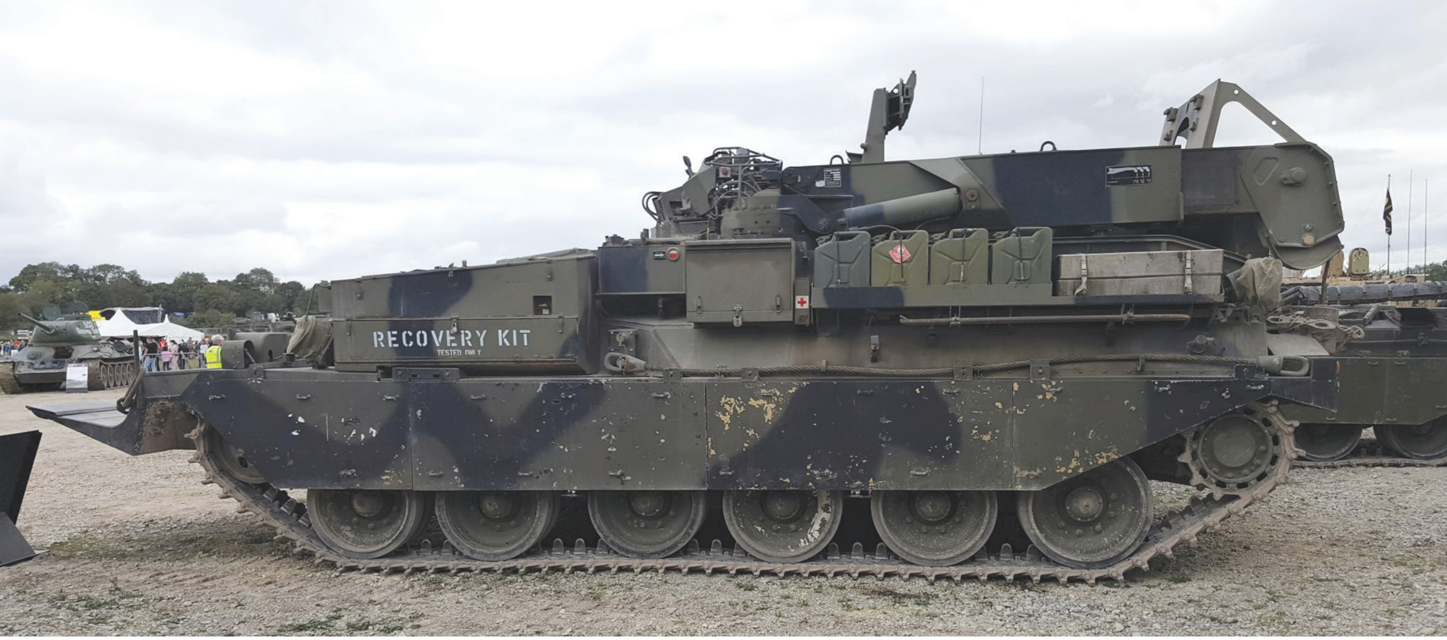
Chieftain tanks saw action in the Iran–Iraq War where they equipped the Iranians. The poor reliability, made worse by inadequate maintenance, and limited mobility placed it at a disadvantage in some engagements with the enemy; however, it was used effectively in some defensive battles. Chieftains were also used by the Kuwait Army during the invasion by Iraq in August 1990. In the battle of the Bridges on 2 August 1990 the out-numbered Kuwait Army Chieftains were used to great effect against the more modern T72s, inflicting a significant number of kills and stalling the advance for a period. In both campaigns the Chieftain demonstrated that it was good at what it had been designed to do – defeating former Soviet Union tanks when fighting a defensive battle.

CHIEFTAIN VARIANTS

A number of Chieftain variants were planned of which the ARV (FV4204) and Armoured Vehicle Launched Bridge (AVLB) (FV4205) went into production.

The FV4204 Armoured Recovery Vehicle was based on the hull of the Mark 5 with the driver relocated to the left side to provide room for the recovery winch. The provision of a front-mounted winch and earth anchor was a significant improvement over the Centurion ARV which had to be reversed into position to recover a vehicle. The vehicle was equipped to undertake self-recovery operations to the rear. The double capstan main winch was capable of generating a sustained pull of 30,500kg and, when used in conjunction with pulleys and the dozer blade, could develop a pulling force of up to 90,000kg. User trials of the ARV were undertaken in 1974 and the first production vehicle delivered and used for field trials from 8 September to 28 October 1975. When Challenger 1 entered service a new Armoured Repair and Recovery Vehicle (ARRV) was introduced based on the Mark 7 hull. This incorporated a crane to lift the Challenger 1 power pack which was beyond the capacity of the crane on the FV434 REME repair vehicle.

The FV4205, which was also based on the Mark 5 hull, was used to deploy either the No.8 scissors bridge, which could span gaps in excess of 22m, or the single-span No.9 bridge, which could span gaps of 12m, using the same hydraulic launcher mechanism. A full FV4205 system consisted of the bridge layer, a No.8 bridge, a No.9 bridge and a wheeled tractor/trailer combination to carry the spare bridge. Development of



Chieftain Repair and Recovery Vehicle still in use at the Bovington Tank Museum. (Author's Collection)

the No.8 bridge started in 1964 and the first of the two prototype AVLB vehicles and bridge sets was completed in 1968. Acceptance for service was agreed in November 1969 but it did not enter service until 1975. The No.9 bridge was developed as a lower-cost system for crossing shorter gaps. Thirty-seven AVLBs were built for the British Army, with the initial order for Mark 5 hull-based vehicles followed up by the delivery of 11 bridge layers based on Mark 6 hulls. The Mark 6-based vehicles were manufactured in 1986 and incorporated improved hydraulics. Fourteen bridge layers were manufactured for Iran.

In 1982 a study was carried out into the conversion of 11 Mark 1 gun tanks into bridge layers. Six main areas requiring modification or fitting were identified; these were provision of a power take-off shaft through the engine compartment bulkhead, provision of a roof to the crew compartment, internal equipment fitments, external fitments, the AVLB launching system and launching system mounting lugs. The conversion was assessed to be feasible but was not implemented.

The Chieftain AVLB saw operational service in Operation *Granby*. One of the challenges to the liberation of Kuwait was the need to cross oil pipelines quickly and safely whilst avoiding damage to the pipes. To address this issue the team at RARDE Christchurch developed modified versions of the No.8 and No.9 bridges which basically incorporated a wedge in the apex of the bridge. This enabled the deployed bridge to

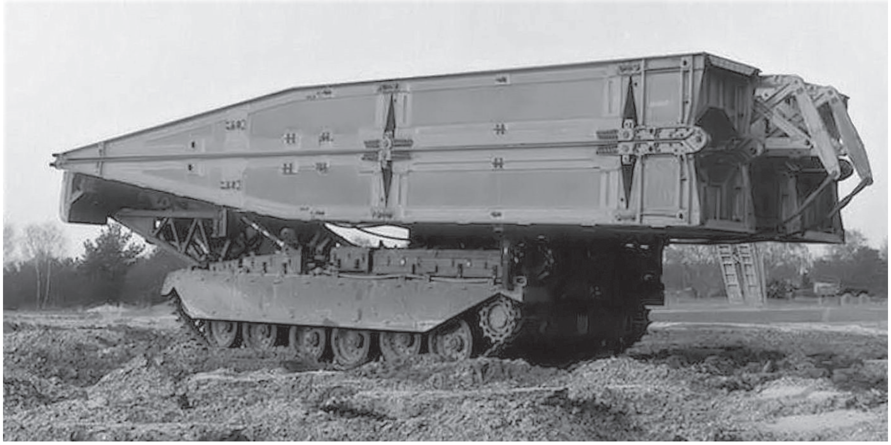
Rear view of Chieftain Repair and Recovery Vehicle with the crane supporting a representative weight ready for tests on the Chertsey tilt platform. (Crown Copyright MOD)

form an arch which cleared the pipeline. Due to the shape of the modified bridge there were times whilst it was being traversed when the driver had limited, or no visibility, of the bridge trackway; therefore to guide him a system of centre line marking poles was developed. These were spring loaded to be pushed out of the way as a vehicle crossed. In addition to modifications to the bridge an additional armour kit was developed for AVLB to provide increased protection against shaped charge weapons over the frontal arc. The kit had to be developed within strict weight limits as the speed and mobility of AVLB was already limited in comparison with the Challenger 1 vehicles it supported. The system selected, following trials, was based on curtain chains hanging from the launch mechanism across the front of the vehicle. This provided protection for much of the special-to-role equipment whilst still allowing restricted, but adequate, vision for the driver. The use of chains also meant there were no constraints on using the launch mechanism. A similar system was also manufactured for the Chieftain AVRE vehicles.

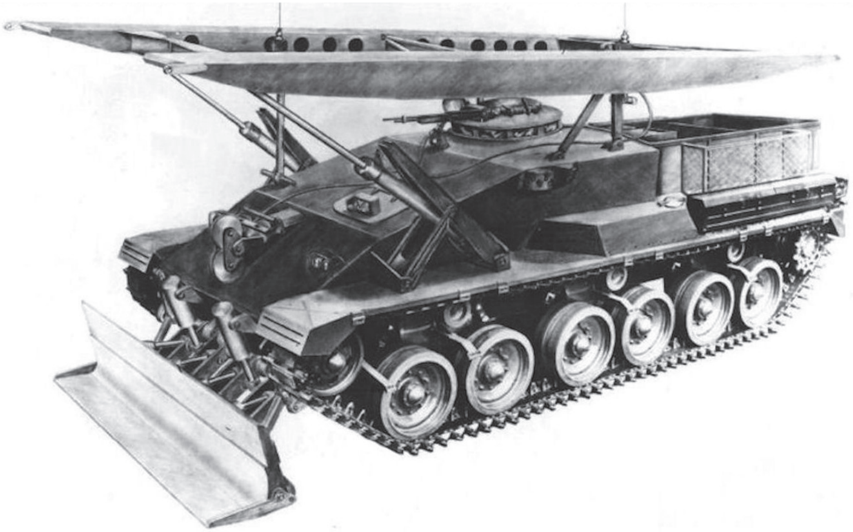
A family of three new combat bridges was developed as part of the Bridging of the Nineties project (BR90), and although initially used with the Chieftain AVLB have been principally used with the Titan bridge layer, developed later, and based on Challenger. These were the No.10, No.11 and No.12 bridges.

- No.10 bridge: Scissors launch mechanism bridge configured to form two different lengths (26m and 22m) by removal of two 4m panel sections;
- No.11 bridge: Formed from four 8m ramp sections to make a 16m-long span capable of bridging up to 14.5m gaps. Launched and recovered by the up and over method and able to be recovered from either end without crew exposure;
- No.12 bridge: Formed of two continuous 13.5m sections launched and recovered using the up and over method. Due to its light weight the AVLB could carry two of these bridges; in use both bridges are launched together and then the top bridge was picked up again by the launch mechanism for final positioning.

Two armoured engineer variants were originally planned, an Armoured Engineer Vehicle (Winch), AEV(W), designated FV4203, and an Armoured Engineer Vehicle (Gun), AEV(G), designated FV4207. The AEV(G) was to mount a 165mm demolition gun in a modified turret and have special-to-role equipment including a dozer blade and hoist. It never proceeded beyond the concept phase. The AEV(W) did reach the prototype phase and undertook user trials; documentation for which



Chieftain AVLB with a No.10 bridge. (Crown Copyright MOD)



Chieftain Armoured Engineer Vehicle (Winch) concept. (Crown Copyright MOD)

used the traditional name of an AVRE. It was based on the ARV and had the same configuration of main and auxiliary winches and a dozer blade which could act as earth anchor when winching or be used for earth moving. It was, however, equipped to launch a compact short single-span bridge. This was launched using hydraulic rams to bring it to the vertical with the main winch then used to lower it into position. During this process the dozer blade was lowered for stability.

The following data is taken from the FV4203 AEV(W) (AVRE) user's guide for troop trials:

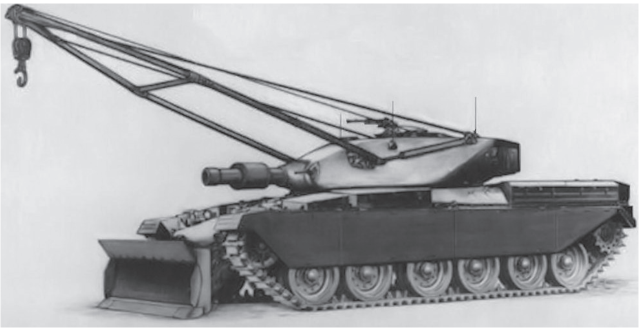
Crew: Five
Weight with bridge: 52 tons
Weight without bridge: 49 tons
Length: 8.077m
Height to top of cupola: 2.692m
Height with bridge: 3.51m
Width: 3.429m
Width with bridge: 3.51m
Armament: One 7.62mm General Purpose Machine Gun (GPMG) on commander's cupola
SIGHTS:
Commander: Cupola AFV No.17 Mark 1 with No.55 Mark 1 gun sight
Driver Periscope: No.45 Mark 1

Main Winch: Pull 298.2kN
Aux Winch: Pull 29.89kN
BRIDGE:
Weight: 3.160kg
Length: 7.73m
Maximum Clear Span: 6.096m

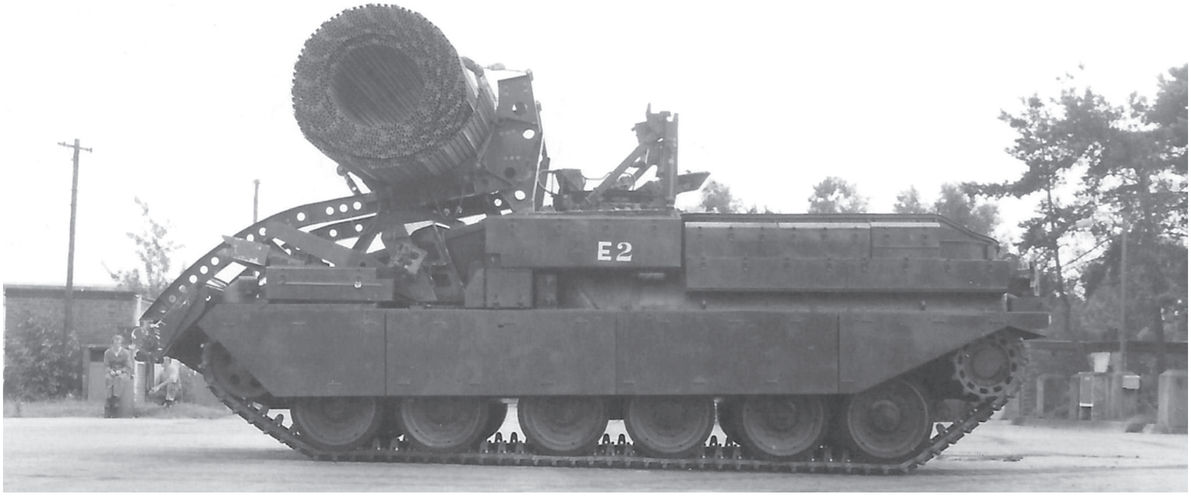
As these AEV variants never went into production, the Centurion Engineer Tank was run on and was still in service at the time of the Gulf War where it was used on the operation.

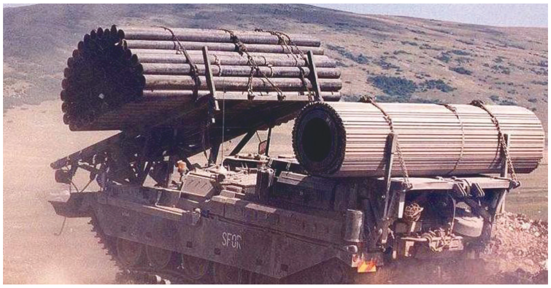
When Challenger entered service, some surplus Chieftain gun tanks were reworked as the Chieftain AVRE with the turret removed and a frame fitted for carrying fascines. The project was driven by the need to replace the ageing Centurion AVRE. Some initial conversions of surplus Chieftains to an AVRE configuration were carried out by the 40 Army Support Group workshops in Willich – the so-called 'Willich AVRE'. In total 17 Chieftains were converted at the workshops using the materials at hand. A formal requirement, Staff Requirement (Land), or SR(L)3949, was endorsed in March 1988 and Chertsey developed a Detailed Technical Specification. In August 1988 Vickers Defence Systems, as Chieftain Design Authority, was tasked with defining a development and production plan and this resulted in a design contract being placed in November 1989 followed by a contract to build 32 vehicles in February 1990. This number was soon increased to 48. Two prototypes were built which were completed in August 1991 and October 1991. The vehicle was accepted for service in September 1992 with the 48 vehicles delivered by 1994. The last two vehicles were conversions of the prototypes to bring them up to production standard.

The intended primary roles for the vehicle were mine clearance, short gap crossing and clearing routes of rubble and obstacles. Secondary roles were the movement of engineering stores and equipment, route denial and digging defensive positions. To undertake these roles the AVRE could carry and deploy fascines or Class 60 trackway. In addition, it could be fitted with a dozer blade or mine plough and could tow a Giant Viper launcher or Bar



Chieftain Armoured Engineer Vehicle (Gun) concept. (Crown Copyright MOD)





TOP
Prototype Chieftain AEV(W)c. (Crown Copyright MOD)

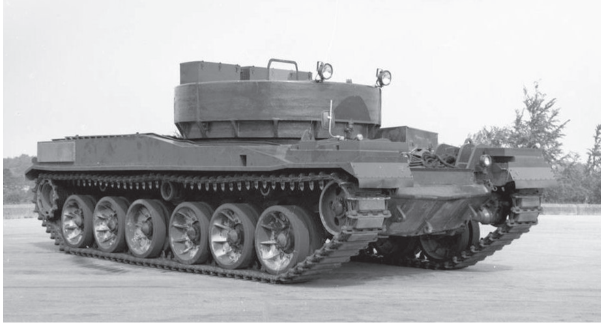
ABOVE
Chieftain AVRE, based on converted gun tanks. (Crown Copyright MOD)

Mine Layer. The maximum laden weight was intended to be 56 tonnes and a crew of four plus two additional passengers could be carried. The hull was retrofitted with the hydraulic track tensioner system developed for Chieftain AVLB.

As well as the formally proposed and fielded variants there were a number of ad hoc and research vehicles based on Chieftain. One of the more unusual conversions was based on one of the two Mark 4 prototypes which had its turret replaced by an NCK Rapier crane for use on the MVEE firing ranges at Kirkcudbright alongside a similar Centurion-based conversion. The other Mark 4 was used as a hydrogas suspension test rig.

One successful research version of Chieftain developed at MVEE was the Signature Integration Demonstrator (SID). This was built to exploit work undertaken as part of the Component Technology Demonstrator Programme (CTDP) which is described in a later section. A less successful Chieftain-based demonstrator built as part of the CTDP was a gas turbine-powered vehicle.

Another research vehicle based on Chieftain built at Chertsey was 'Crazy Horse', a remote control vehicle intended to be used as a mobile target for testing weapon systems. Although the Germans had fielded some small radio-controlled unmanned tracked vehicles to carry explosive charges in World War II, Crazy Horse was the world's first fully radio-controlled tank.

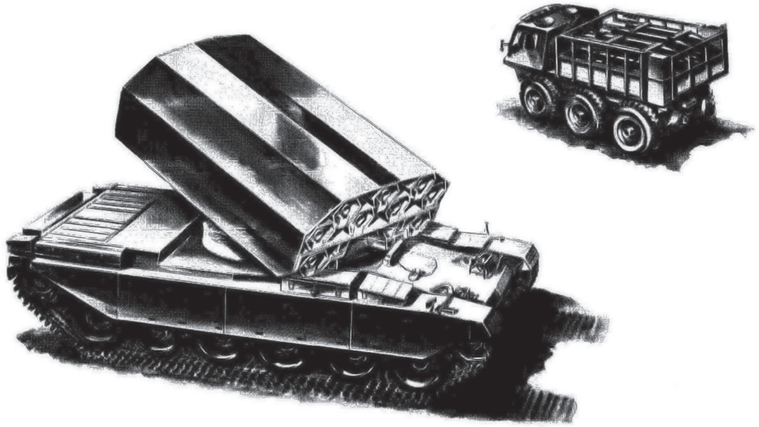


Chieftain Mark IV hull '02 SP 96' in use for testing of hydrogas suspension units and fitted with a 'Windsor Turret'. In this guise it was called 'SPR5'. (Crown Copyright MOD)

A number of private venture variants were produced but never went into production, including:

- Chieftain 900: A version designed by ROF Leeds and aimed at exports. First exhibited in 1982 it consisted of a heavily modified Chieftain fitted with Chobham armour and powered by a 900hp Rolls-Royce CV12 engine;
- Chieftain GBT155: A Chieftain hull fitted with a 155mm Universal Gun Turret developed by Vickers Shipbuilding and Engineering Ltd (VSEL);
- Chieftain Sabre: Chieftain hull fitted with a Sabre anti-aircraft gun turret developed by ROF in the UK and Thompson CSF in France and fitted with twin 30mm cannons;
- Chieftain Marksman: Chieftain hull fitted with a Marconi command and control system Marksman anti-aircraft gun turret with twin Oerlikon 35mm cannons.

One variant of Chieftain that did not develop beyond an initial concept was a field artillery rocket system that was proposed in 1967. Chieftain was one of a range of platforms considered for what was called the FOIL ground-to-ground rocket system and with ten carried was the version with the most rockets fitted.

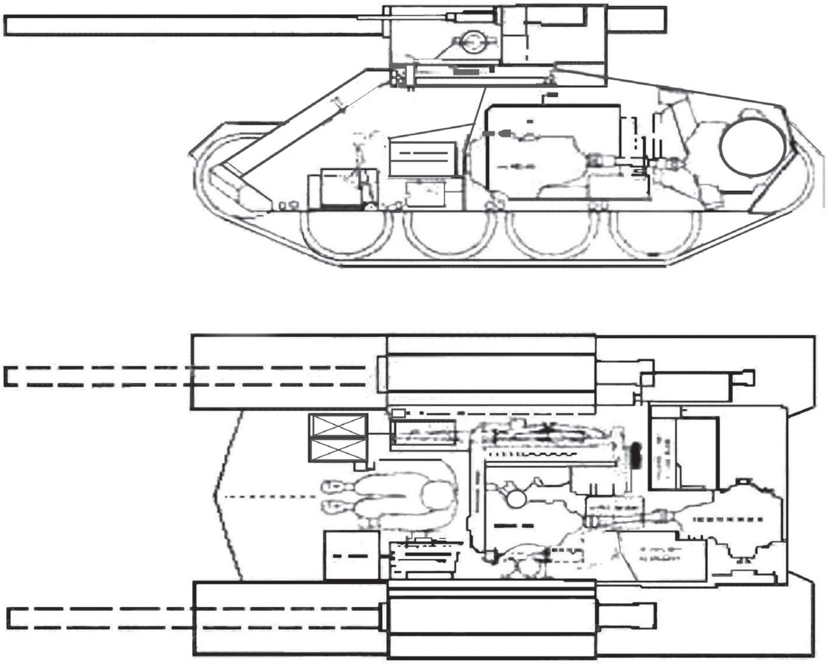


Chieftain Field Artillery Rocket System concept designed to carry and launch ten ground-to-ground missiles each of which was 2.9m long, 178mm in diameter and weighed 159kg. (Crown Copyright MOD)

NOVEL CONCEPT STUDIES

Even with the design and development of Chieftain well in hand there was still a significant amount of concept work ongoing at Chertsey studying potential technologies and designs for future tanks. Much of this was driven by the perceived requirement for improved mobility for tanks on the nuclear battlefield; this led to a call for lighter faster tanks but without compromising the firepower or protection.

In the early 1950s work started on a vehicle called ‘Contentious’. Contentious sought to take a radical approach to the provision of a tank destroyer capable of providing the firepower of FV214 within a smaller, lighter and cheaper package (aimed to be a quarter of the cost). The initial concept, which was reported on in a significant amount of detail in a 1953 report, was for a tank crewed by a single operator. The running gear and power train were based on the FV400 series (Cambridge Carrier), but upgraded to carry additional weight. The engine was to be Rolls-Royce B81 which was an uprated version of the B80 used in the



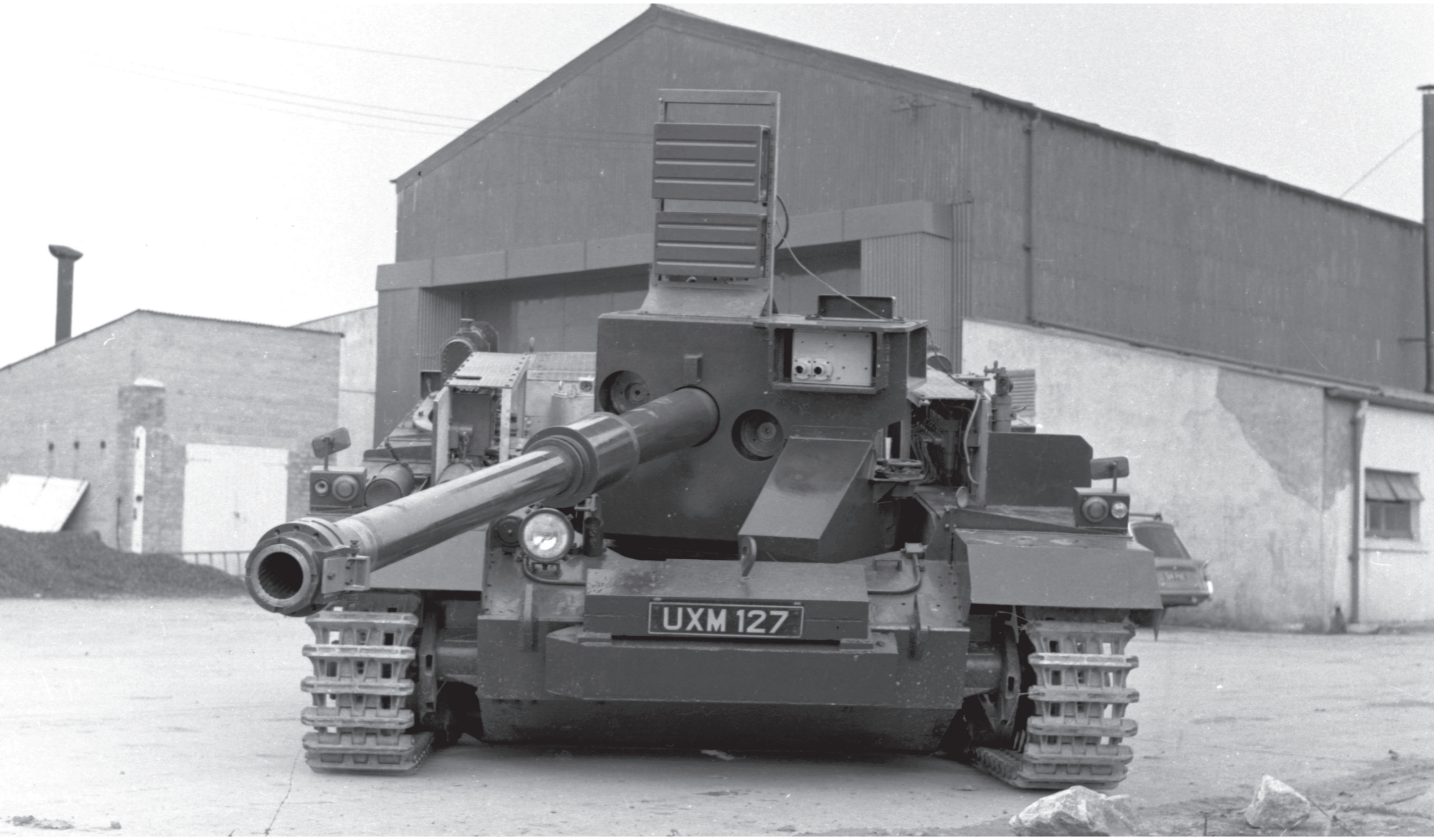
Concept for Contentious 1 with single crew member abd two 120mm guns. (Crown Copyright MOD)

Cambridge Carrier. Gun, missile and rocket versions were considered, the missile version with three missiles and the rocket version with 18 rockets – each with a 5in. warhead. The gun option was recommended for further study; the initial design mounted four 120mm guns each with a single round ready-loaded, but following user feedback this was revised to two 120mm guns each with a seven-round revolving autoloader. The guns were to be mounted on a cupola giving +/-20 degrees of traverse and +10/-5 degrees of elevation. To meet the requirement for low cost, no stabilization was fitted for firing on the move but a ranging machine gun was planned to give a high probability of first round hit when static. The frontal armour was 6in. (152mm) thick and well sloped and side armour was 1in. (25mm) thick, but at 6ft 5in. (1,956mm) high and 8ft 3in. (2,515mm) wide (compared with 11ft 2in. (3,404mm) and 13ft 1in. (3,988mm) of the Conqueror) its small silhouette was expected to provide significant survivability benefits. It was calculated that the all-up weight would be 15 tons.

User feedback on the concept highlighted a number of concerns, including:

- The viability of a single operator;
- Vulnerability of the external guns;
- Lack of rounds (14 only) – the user expressed a preference for a single gun and more rounds;
- Accuracy of the guns – only likely to be accurate enough out to 1,000 yards;
- The need for improved mobility for the nuclear battlefield (the mobility would have been similar to that of Centurion).

As a result of the feedback initial schemes were developed for a new two-crew tank concept and these were reported in 1955. Following further refinement detailed concepts were developed and reported in August 1959. The new concept, Contentious II, had two crew members plus an autoloader and mounted a limited (+/-20 degrees) traverse gun in the hull, rather than a rotating turret. The basic dimensions were: length 5,490mm, height 1,980mm and width 2,900mm. Gun elevation was to be achieved by tilting the whole hull through the use of adjustable suspension with the goal of providing up to 18 degrees of elevation. In order to assess the feasibility of this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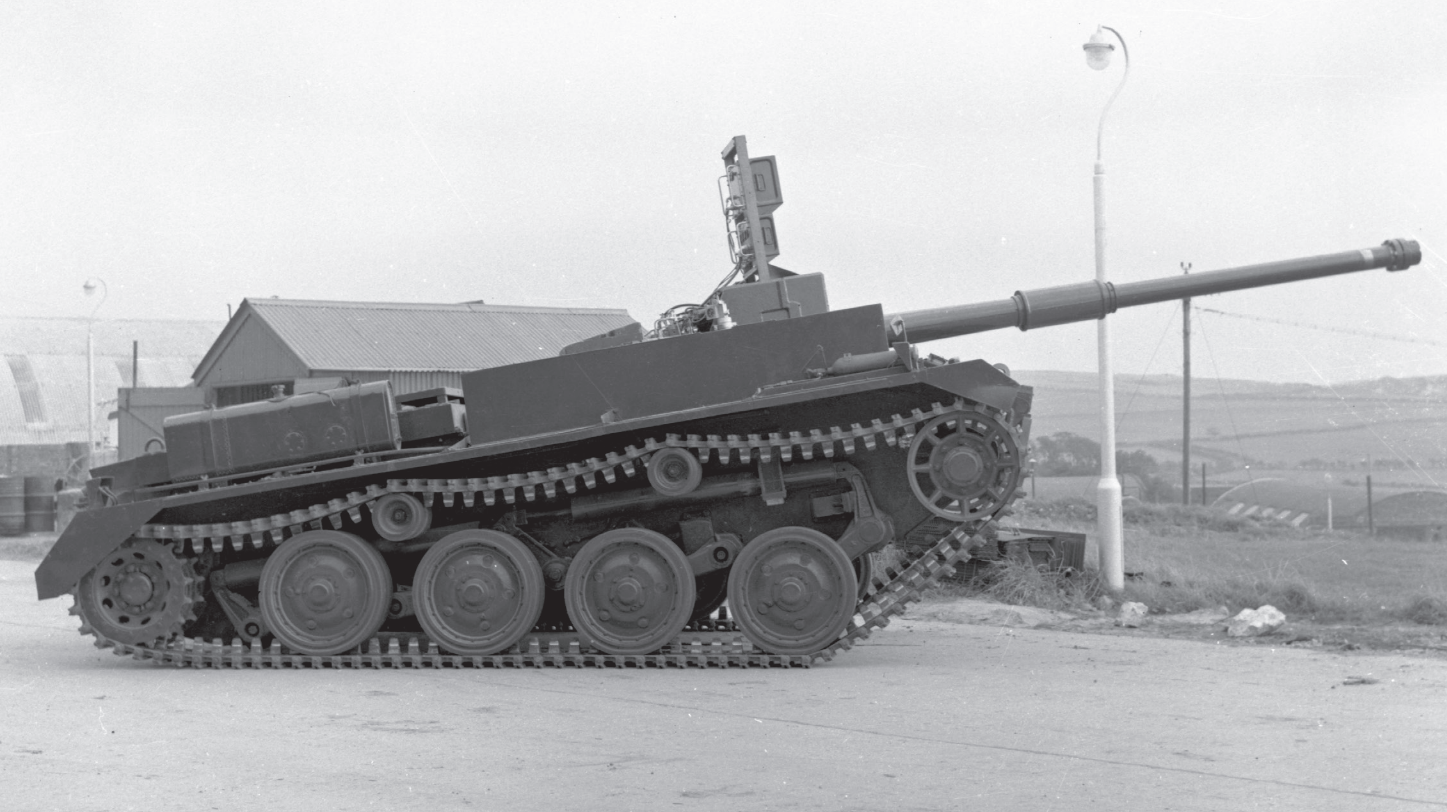


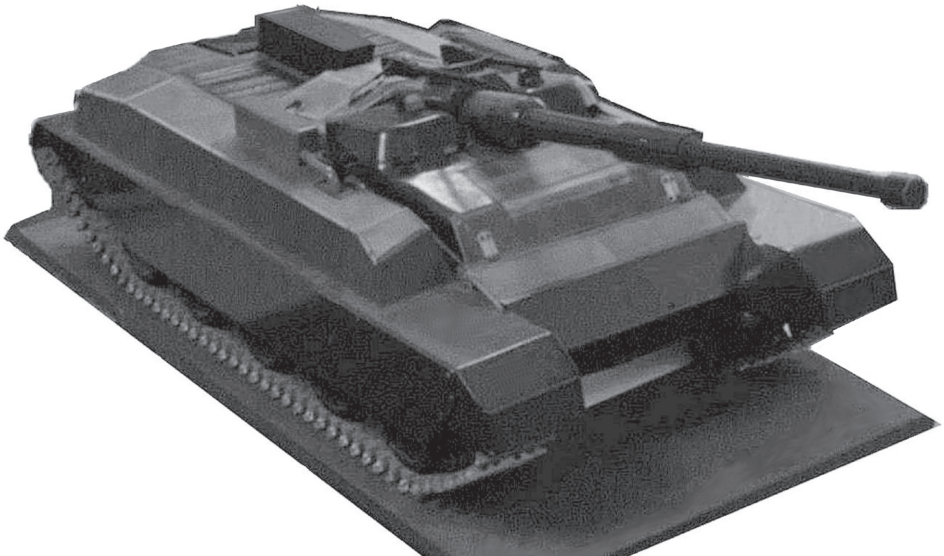
concept for gun-aiming, a Comet-based demonstrator was built with four road wheels and adjustable suspension. The calibre of the gun was to be 120mm, but 155mm or 160mm low-pressure guns firing HESH at a lower muzzle velocity were also considered. In addition, a coaxial 76mm gun (as fitted to Saladin) was incorporated to provide an HE capability. The crew sat side by side and either crew member could drive the vehicle or fire the gun. The proposed engagement cycle was based upon the commander taking control of driving on acquiring a target and slewing the vehicle so that the target could then be tracked by the gunner over the 40-degree arc of available traverse. Missiles had again been considered for the main armament but rejected due to the low rate of fire – trials had indicated that with its gun Contentious II could potentially engage and hit 16 targets in a minute. Frontal Arc protection was to be provided by two 40mm steel plates with a gap of over 1.2m between then. The slope of the plates plus 'ribbing' was claimed to improve performance against armour-piercing rounds. The large gap between the plates was to be utilized as a fuel tank, further enhancing protection, and giving protection over the frontal arc equivalent to 150mm of homogeneous steel armour. A polythene liner impregnated with boron was to be provided to enhance protection against neutrons which it absorbed. It also reduced the impact of fragments from the round and armour (spall) if penetrated by reducing their spread. The power pack was to be a multi-fuel engine of between 350hp and 500hp. It was recognized there were no suitable engines available but an engine bay mock-up was built to start scoping the size and packaging requirements. It was calculated that the overall weight would be approximately 20 tons, although schemes up to 30 tons were looked at which had enhanced crew protection. Other novel features being considered included a photoelectric gun control system and a pulsed light ranging system. At the UK/US/Canadian armour conference in 1958 the UK reported that a test hull for Contentious, weighing around 13½ tons, had been used in air drop tests from a Beverley aircraft. At the time the US was interested in the Contentious concepts as a requirement for a 25–30-ton vehicle to replace the M48 had been identified. A wheeled variant, potentially with hydraulic drive, was considered as a follow-on from the initial tracked version and design data was carried across from the TV1000 wheeled demonstrator which is discussed later.

OPPOSITE
Contentious 2 weapon aiming demonstrator showing the limited traverse weapon and elevation solution using adjustable suspension. (The Tank Museum, Bovington)

The ARDE at Fort Halstead had been investigating feasibility of using liquid propellant for the main gun and had carried out numerous firings from modified 77mm and 20-pdr guns. By 1956, ARDE had done enough work to believe that the use of liquid propellants was viable, although a major issue still being addressed at the time was a lack of consistency in performance. ARDE did, however, start discussions with FVRDE about the feasibility of a liquid propellant (LP) gun tank which resulted in some concept studies at Chertsey. One potential concept was illustrated by the build of a scale model. It reflected some of the ideas from the Contentious study, including the use of a two-man crew and a limited traverse gun. Unlike Contentious, gun elevation was achieved through elevating the complete crew compartment which comprised a separate pod.

Despite the potential benefits of liquid propellant guns they were not taken forward due to the ongoing issues with consistency, the corrosive nature of propellants and the challenges of supplying them to a breach with elevation and recoil movements to be taken into account. Although work has since been carried out by a number of nations, including the UK, liquid propellant guns are yet to be fielded on production weapon platforms.

The later phases of the Contentious project fed into another project – called Prodigal – which covered long-term concept development and technology risk reduction for a family of 20–30-ton armoured vehicles to be fielded around 1970–75. Research activities under the Prodigal programme addressed a number of the technology challenges highlighted by the Contentious studies, including autoloaders (with seven design concepts being assessed) and weapon accuracy. The user



Two-crew liquid propellant tank concept model with limited traverse gun and elevating pod. (Crown Copyright MOD) requirement to improve accuracy at long ranges led to research into additional barrel supports forward of the gun cradle. This arrangement was possible with a gun with a fixed elevation and was intended to ensure that the barrel remained straighter whilst allowing recoil; trials were carried out using a 105mm barrel. The line of study did not provide the hoped-for improvements, however, the data generated and the instrumentation solution for monitoring the muzzle position did lead to very successful work on muzzle reference systems. An initial concept study report on potential concepts and technologies for Prodigal was issued in 1960. This report was supported by a specific study on weapon options which included an assessment of the US 152mm Shillelagh weapon system which could fire tube-launched missiles from the gun barrel.

In the early 1960s, even before Chieftain had entered full production, long-term concepts for a possible replacement started to be considered. An initial GSR, 1008, for Chieftain replacement was issued in June 1961. In May 1962 a 'War Office Policy Statement' on weapons and equipment outlined the high-level requirements for a tank to replace Chieftain with a focus on firepower and protection to compensate for the likely numerical superiority of the enemy. These were:

1. Ability to engage enemy armour out to 5,000m by day and night.
2. Ability to engage low flying aircraft and aerial vehicles.
3. A high level of protection against kinetic energy and chemical energy (shaped charge) rounds, mines and flame attack.
4. Freedom of movement including the ability to cross water obstacles with the minimum of preparation.
5. Bridge classification Military Load Class 50.[6]

It was also stated that the vehicle should be a joint development with the US and Canada. In 1965 a proposal was made for a two-vehicle solution to meet the future MBT requirement. The vehicles were to weigh around 30 tons, have a power-to-weight ratio of 27bhp/ton, be protected by Burlington (Chobham) armour, which was then in the early stages of development, and have a crew of two. Both vehicles were to have mounted a 30mm cannon as an auxiliary weapon but one was to have Swingfire missiles, stowed under armour, as the main weapon and the other a low-pressure 105mm gun. The 105mm gun was to be similar to that fitted to Abbot but have the capability to fire a High Explosive Anti-Tank (HEAT) round for shorter-range anti-vehicle use. The proposed two-vehicle solution was not acceptable to the Army and so studies focused on a single-vehicle solution fitted with a high-velocity anti-tank gun. An emphasis continued to be placed on reducing weight whilst maintaining firepower and protection and so by 1966 FVRDE was evaluating a range of concepts in the 40–50-ton range. One potential way of reducing weight that was considered was the use of an external gun with an autoloader in place of a manned turret. This approach had the potential to provide significant weight reductions as a manned turret can typically contribute around a third of the overall weight of an MBT. Such a configuration also reduces the frontal area when in a hull-down fire position and enables the crew to be located where they are least vulnerable – down in the hull. In 1968, in order to explore the concept of an external gun and demonstrate its viability, FVRDE built the world's first external gun demonstrator. It was based on a Comet hull and

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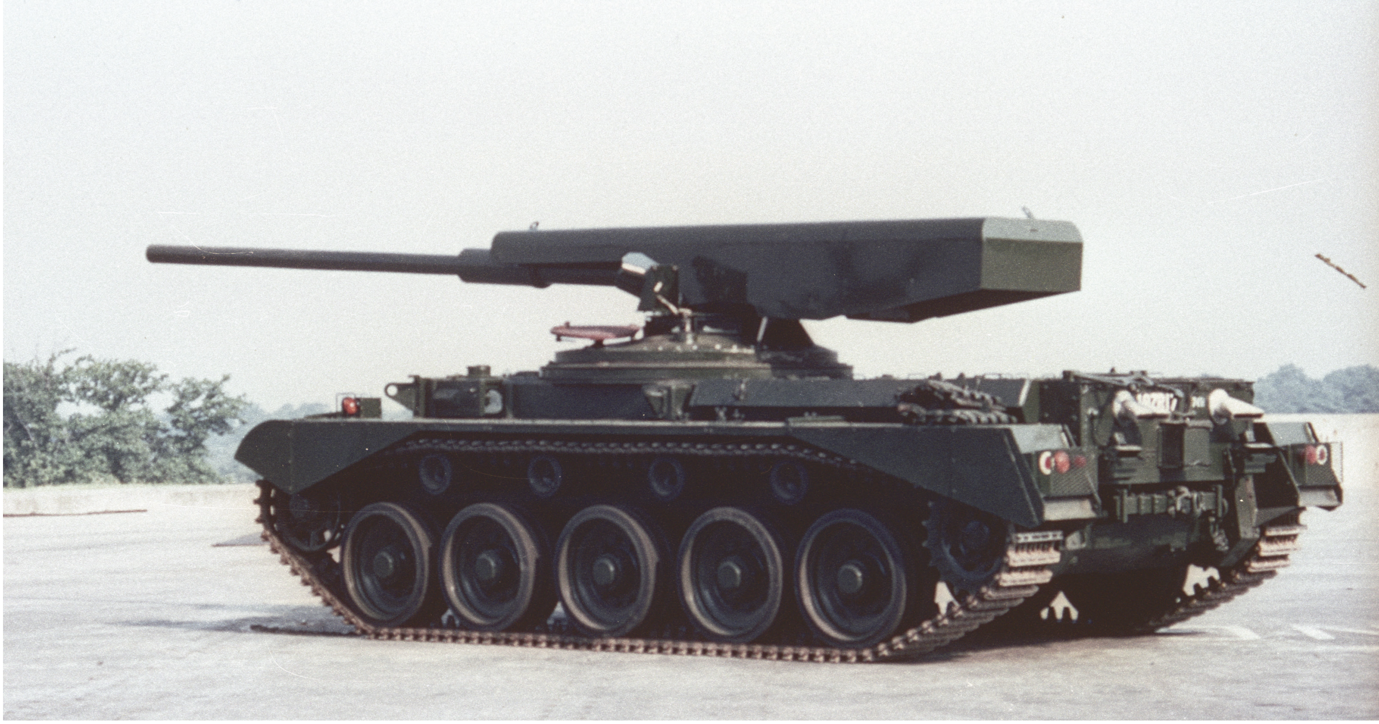
[6] This equates to around 45 tonnes for a conventional tracked vehicle.



COMRES 75, the world's first tank with an unmanned turret, based on a Comet tank hull. (The Tank Museum, Bovington) mounted an 83.8mm gun with autoloader; it was called the COMRES 75. Demonstrating the viability of a reliable autoloader was an important goal of COMRES 75 as this was essential if such a concept was to be accepted by the Army. The work on COMRES fed directly into the next stage of studies into a replacement for Chieftain.

On 1 January 1969, the Executive Committee of the Army Board (ECAB) issued a paper on the requirements for future AFVs which were to be focused on fighting a European-based war in the 1980s and 1990s. The paper was partly driven by the planned replacement of FV432 which was due to begin to be withdrawn from service from 1978, at which time it would start to be replaced by a new Mechanised Infantry Combat Vehicle (MICV); there was also the recognition that Chieftain would need to be replaced from the mid-1980s. Therefore, ECAB requested a study into a coherent family of armoured vehicles covering medium-weight platforms, a future tank capability and supporting vehicles. As well as developing concepts for a heavy tank, ECAB requested that the study should also consider concepts for a medium-weight tank based on MICV; hence allowing a comparison between the two sets of concepts. In order to respond to the direction given by ECAB the 'AFV for the 80s' project was initiated. The project was planned to be carried out in three stages. Stage 1, described later, was a study into a fleet of medium-weight vehicles including an MBT. Stage 2, which followed directly on from Stage 1, was a study into heavy MBT concepts and other heavy variants for roles that could not be covered by a medium-weight solution. Stage 3, a study into self-propelled anti-tank systems, was carried out later as it was seen as lower priority and could not be accommodated within the available resources at Chertsey.

It was agreed that initially three concepts would be considered as part of the Stage 2 study covering heavy Main Battle Tanks:

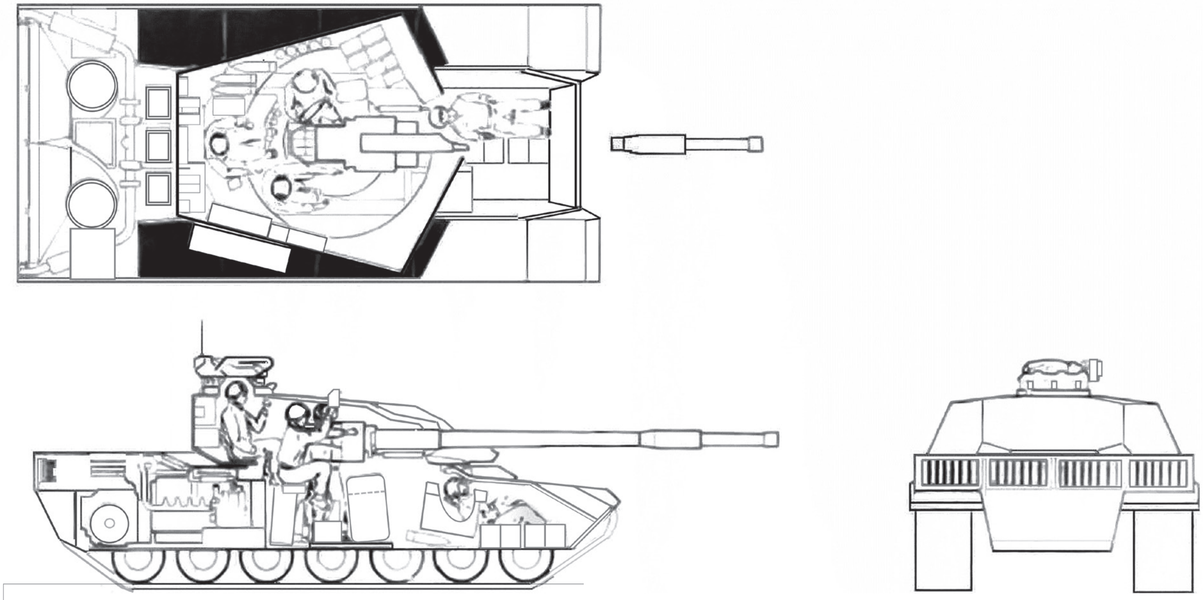
- Conventional 55-ton (Class 60) MBT;
- Conventional 47-ton (Class 50) MBT with reduced protection;
- External Gun 47-ton (Class 50) MBT.

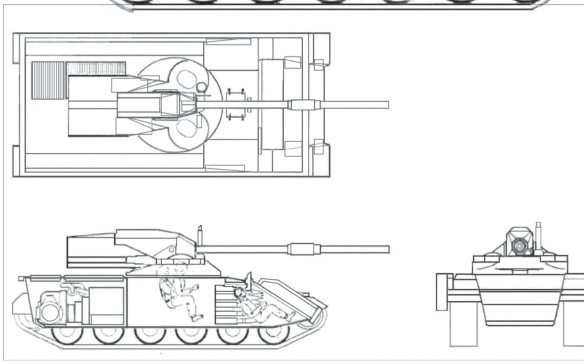
These were to be assessed along with a medium-weight (35-ton) MBT with an external gun, based on MCV80 components, as defined in the Stage 1 study. MCV80 was the designation for the infantry fighting vehicle then under development which was eventually fielded as the Warrior vehicle.

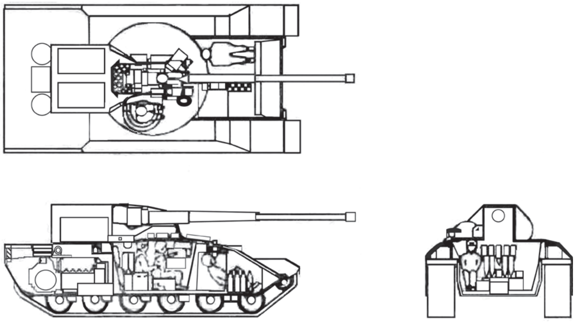
The 47-ton 'heavy' external gun tank was to be designed to have the same level of armour protection as the 55-ton conventional MBT demonstrating the weight benefits of an external gun. The COMRES 75 demonstrator and subsequent design studies showed that potentially the rotating mass of an external gun could be kept to about 6.5 tons, compared with the 16 tons of a conventional manned turret.

The concepts were based around the promising 110mm gun being developed at the time which potentially had better armour penetration performance than the in-service 120mm gun on Chieftain along with the advantages of being more accurate and lighter. This gun was originally developed specifically for use in an external gun tank and had one-piece ammunition. However, the project went on to develop two-piece ammunition for use in conventional manned tanks.

An initial Stage 2 study report was issued in April 1971 and the findings reviewed the following month in order to provide guidance for the next phase; this was intended to be developed into more detailed designs to better validate the concepts and generate more accurate estimates of parameters and performance. The review recommended the inclusion of fixed-gun concepts similar to that of the Swedish S-Tank; two of which had been evaluated by the Army in 1968. The S-Tank had significant advantages in terms of reduced silhouette and weight but there were concerns about reliance on the suspension for controlling weapon elevation. The recommendation resulted in the inclusion of two additional concepts in the next phase, one with a semi-fixed gun in the hull, moving in elevation only, and a pod concept where the gun was fixed in a crew pod that elevated. Trials with the S-Tank had concluded that turning the tank for aiming in azimuth was satisfactory. It was recognized, however, that the heavier better-protected UK concepts would have much longer lengths of track on the ground than the S-Tank which would present more of a challenge for accurate azimuth control. The initial study had investigated potential solutions for the main platform sub-systems and made a number of recommendations to feed into more detailed design studies. The gun was fixed as the 110mm, Burlington (Chobham) armour was considered mature enough for consideration, as was hydrogas suspension. The engine was to be a Rolls-Royce CV8 or CV12 (although many of the actual concepts finally generated had a CV10). At the time there was promising research into diesel Wankel engines and this technology was not ruled out. One area







ABOVE LEFT AND RIGHT
AFV of the 80s Medium Weight External Gun concept. (Crown Copyright MOD)

TOP
AFV of the 80s Class 50 External Gun concept. (Crown Copyright MOD)

that was identified as having significant risk was the vision systems for the external gun concept. Thermal imaging was seen as promising but regarded as being high risk at that time. The concepts were therefore assumed to use 'TV based' systems and the report recommended work be carried out on improved 'Vidicon Tubes' to provide the required display screen resolution. Another area recommended for further studies was autoloaders. COMRES had shown the viability of an MBT with an autoloader but further development work was seen as necessary to ensure systems could be developed that could reload reliably on the move.

The study proceeded with the three initial heavy concepts being refined and the turretless semi-fixed and elevating gun concepts generated. The final report, issued in February 1972, presented six main concept designs for the heavy tank solution; these were intended to inform the way ahead for finding 'a worthy successor for Chieftain' and were:

- Conventional 55-ton tank;
- Lighter 45-ton conventional tank with fewer stowed rounds and reduced protection levels;
- External gun concept with ready rounds and autoloader integrated behind the gun;
- External gun concept with ready rounds and autoloader installed in the hull;
- ‘Conventional’ semi-fixed gun concept;
- Fixed-gun concept with crew in an elevating pod.

The key parameters for these concepts are given in Table 4.

Table 4: **Main parameters of the AFV for the 80s Heavy MBT Concepts**

	Class 60 Conventional MBT	**Class 50 Conventional MBT**	**External Gun: External Magazine**	**External Gun: Rounds in Hull**	**Semi-Fixed Gun Concept**	**Elevating Pod Concept**
Crew	4	4	3	3	3	3
Length/m	9.567	9.186	8.365	8.340	9.017	9.200
Hull length/m	7.854	7.331	7.090	7.090	6.985	6.960
Width/m	3.630[7]	3.506	3.945	3.945	3.505	3.600
Height/m	2.900	2.900	2.720	2.900	2.667	2.690
Weight/kg	54.884	47.775	47.775	47.775	47.775	47.775
Fuel Tank/l	1,137	1,115	1,115	1,115	1,115	1,115
Armament	110mm	110mm	110mm	110mm	110mm	110mm
Elevation/Depression (degrees)	+20/-15	+20/-15	+15/-10	+15/-10	+15/-10	+15/-10
Stowed Rounds	50	40	40	40	40	40
Engine Type	CV12	CV10	CV10	CV10	CV10	CV10
Engine Power (bhp)	1,125	938	938	938	938	938
Suspension	Hydrogas	Hydrogas	Hydrogas	Hydrogas	Hydrogas	Hydrogas
Road Wheels/Side	6	6	6	6	6	6

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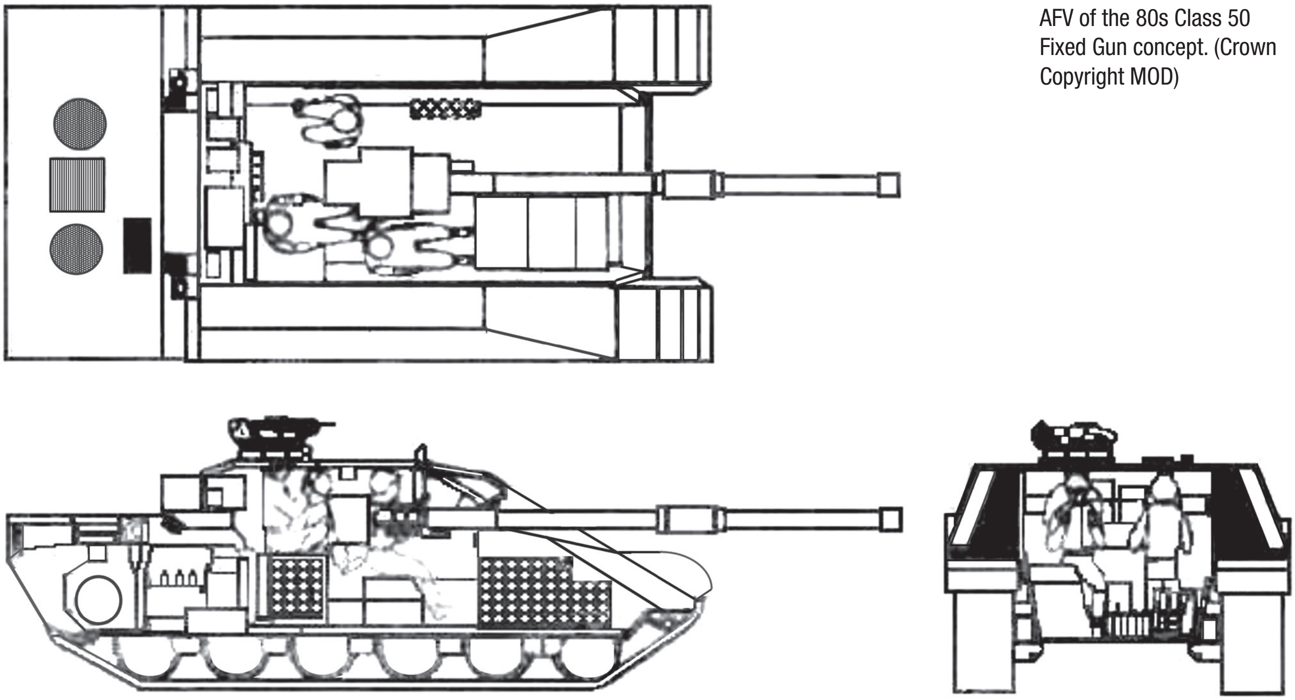
[7] Wider with side Chobham armour packs fitted.

By the end of the second phase of the Stage 2 study, work on the various concepts had reached different levels of maturity. Full-scale wooden mock-ups had been built of the two conventional turreted concepts and the external gun concept with the external magazine. A partial mock-up had been made of the other external gun concept but the two semi-fixed gun concepts were just at the paper design stage. The full-scale mock-up of the 55-ton concept had already been used by the Army for stowage and human factors trials. The concept that was recommended from the Stage 1 study was the medium external gun concept and this was assessed alongside the heavier concepts.

In addition to the main concepts a small number of 'trade-studies' were carried out into some variations. These included fitting a 90mm gun to the 47-ton conventional concept, different engines and different types of autoloader. One of the more extreme design excursions looked at a 110mm gun in a limited traverse (+/-45-degree) turret. This concept had the driver in the turret but was discarded as having significant disadvantages compared with the main concepts whilst providing little improvement in terms of survivability or weight reduction.



AFV of the 80s Class 50 Fixed Gun concept. (Crown Copyright MOD)

The conventional 55-ton (Class 60) concept was recommended as the best overall option, being much lower risk than the alternatives. It provided significant benefits over the Chieftain with improved firepower and protection, and would have had '50 per cent better mobility'. No significant differences were identified between the two external gun concepts. The hull protection level for these was as good as that of the recommended conventional concept but, at around 7 tonnes lighter, that provided to the weapon system was limited. The semi-fixed gun concepts provided no significant improvements in protection over the other concepts and had significant drawbacks in terms of operational utility.

During the period of the AFV for the 80s study FV4211, described below, was built, therefore in the final report the recommended concept was also assessed against that vehicle as well as Chieftain and the preferred Stage 1 Medium MBT concept (Table 5).

Table 5: **Comparison of the AFV for the '80s and FV4211 as Chieftain Replacements**

	Chieftain	FV4211	Conventional 55ton Concept	Medium (MCV80 based) MBT External Gun
Crew	4	4	4	3
Weight (tons)	53.2	55.2	55	35.1
Power to Weight (hp/ton)	12.22	13.46	20.5	21.4
Armament	120mm	120mm	110mm	110mm
Length				
Gun Forward	10,795mm	10,617mm	9,567mm	8,460mm
Hull	7,518mm	7,746mm	7,854mm	6,900mm
Height	2,870mm	3,200mm	2,940mm	2,570mm
Width	3,505mm	3,912mm	4,072mm	3,600mm

By the time AFV for the 80s Stage 2 study reported, the decision had been made to pursue a joint UK-German solution for a new MBT, therefore the study was stopped but the data and findings of the work were fed into that programme.

UK/GERMAN FUTURE MAIN BATTLE TANK

In the late 1960s the decision was made to explore whether the next Main Battle Tank (Future Main Battle Tank – FMBT) could be a UK-German collaboration. This decision was based on the fact that at that time both nations were planning a Main Battle Tank replacement programme to enter service around 1985, the UK replacing Chieftain and Germany, Leopard 1. In 1970 a meeting was held between the respective Army Chiefs and by 1971 there was general agreement on a joint General Staff Target. An Anglo-German technical symposium was held in May 1972, after which plans for a joint development programme started to be drawn up. At the symposium the idea of an external gun was discounted but Germany expressed much interest in a turretless tank with the gun mounted in the hull. The symposium concluded with an agreement that a joint feasibility study be carried out. During 1973 an agreement was reached on a broad division of development responsibilities; however, the work share situation was complicated by parallel work on a standardized NATO gun which involved the US under a project called the Tripartite Tank Main Armament Evaluation Programme. The armament was planned to be either a 110mm or 120mm gun. At the time, RARDE was working on a 110mm gun which, as discussed, had already been assumed as the main armament for the AFV for the 80s concepts. The weapon development work was being carried out in three phases:

- Phase 1: Initial 110mm gun demonstrator based on the 105mm design;
- Phase 2: Revised barrel design to increase stiffness and reduce dispersion;
- Phase 3: Revised breach design to fire two-part rather than fixed ammunition.

It was agreed that two sets of concepts would be considered during the joint feasibility study; turreted concepts with a weight target of 55 tons (Class 60) and semi-fixed gun concepts with a weight target of 48 tons

(Class 50). A German preference was for a vehicle that could meet the Class 50 bridge classification constraints; they placed a high reliance on mobility for survivability and this drove the target 48-ton limit. It was clear that the armour protection requirements could not be met with a conventional turreted tank at 48 tons; hence the interest from Germany in the semi-fixed gun concepts.

Power packs under consideration were Rolls-Royce CV12 or CV16 and the MTU871 and 873.

The initial plan for the joint FMBT was:

- Feasibility study complete by January 1977;
- Project Definition Phase 1 complete by October 1978;
- Project Definition Phase 2 complete October 1979;
- Full development complete by end 1984;
- First of production 1987.

The timescales soon started to slip. At the May 1972 symposium it had been agreed that the two nations would generate and exchange information on their concepts by December 1973, to be followed by a review period where each nation assessed the other's proposals. As the concept development in Germany was carried out by industry there were delays in the work starting due to the need to place contracts and the concept data exchange slipped to October 1974.

MVEE developed a semi-fixed gun concept which had some features first considered for Contentious and refined during the AFV for the 80s study. Unlike the S-Tank, which had a fixed gun, the MVEE concept enabled the gun to elevate from -10 to +20 degrees and traverse +/-2 degrees allowing fine tracking without moving the hull. The concept was much better protected than the S-Tank and so weighed 54 tonnes compared to 39 tonnes. Meanwhile, in 1973 the Army carried out a further assessment of the S-Tank using ten loaned vehicles. Following crew training in Sweden in July and vehicle trials and assessment running from 27 August to 7 September the ten vehicles were transported to Germany for use in Battle Group exercises (Exercise Dawdle). The user assessment concluded that the lack of turret and inability to fire on the move was too restricting. Despite this some further work was carried out on the MVEE turretless tank concept, which adopted the German name of Casemate, and a Casemate Test Rig was built based on Chieftain components. It made extensive use of aluminium to minimize weight but was wider than Chieftain and had a modified engine compartment so that a ten-cylinder MTU engine could be fitted in place of the L60. The barrel was a dummy tube, although use of a 120mm gun was envisaged, as was the fitting of Chobham armour. The demonstrator was transferred to the Bovington Tank Museum in 1990 where it is often referred to as the JagdChieftain. It was less complex than the German contribution to the study which had two guns for improved first round(s) hit and attempted firing on the move by coincidence firing when zigzagging. The German turreted concepts included both conventional layouts and 'Driver in Turret' or DIT concepts. MVEE analysis of the German turreted concepts concluded that they would exceed the 55-ton weight target, estimating both at over 60 tons. The DIT concept required a large turret and turret ring, and so would not have fitted inside the rail gauge for transportation.

MVEE carried out analysis into the weapon accuracy of the various options including an assessment of the design and performance of a two-gun concept. Design issues studied included the relative off-set of the main sight to the two barrels, the blast effect of two barrels firing near simultaneously and the impact of slight variations in actual firing time on the accuracy of the delayed round. These studies indicated that there were no fundamental design challenges that precluded the use of two barrels. Slew rates were also considered and it was calculated that under ideal conditions a fixed gun tank could slew the gun at 750mil/sec, although in practice with less-than-ideal ground conditions it would probably be somewhat slower. The predicted slewing performance compared well with that of the Chieftain Turret, at 400mil/sec, and be considerably better than the S-Tank at only 89mil/sec. The analysis also confirmed the potential increased probability of 'Target Kill' using two barrels (Table 6).

Table 6: **Comparison of the Probability of Kill for a One- and Two-gun FMBT Concept Against a Representative Target**

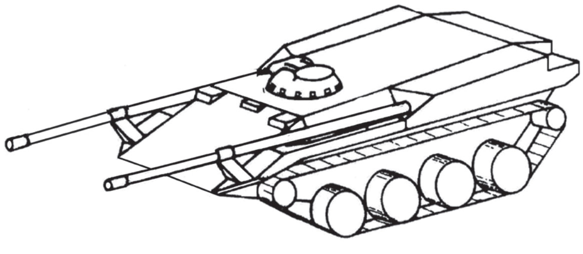
Target Type	Range	Two-gun FMBT	One-gun FMBT
Moving	1,000m	0.96	0.86
	2,000m	0.81	0.57
	3,000m	0.55	0.34
Static	1,000m	0.97	0.89
	2,000m	0.88	0.65
	3,000m	0.60	0.39

Following the various studies the preferred FMBT concepts selected by the UK for further development were:

- UK1: Semi-fixed gun Class 60 concept with a 110mm gun and a V16 engine;
- UK2: Conventional Class 60 MBT with a 110mm gun and a V12 engine;
- UK3: Conventional Class 60 MBT with a 110mm gun and a V16 engine.

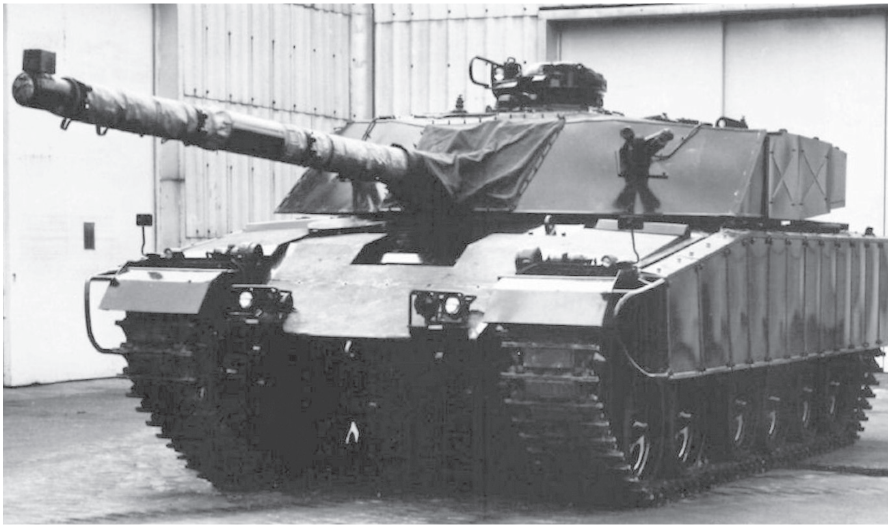
Since 1970, in parallel with the FMBT studies, Germany had also been developing an improved version of the Leopard tank as a replacement for its M48 tanks. Named Leopard 2 in 1971, this vehicle incorporated the power pack and other technologies from the German/US MBT70 project. By 1976 the Germans had concluded that FMBT, as envisaged, would provide only limited benefits over Leopard 2, especially as analysis of lessons from the 1973 Yom Kippur War had already led to an increase in armour protection on that vehicle. The increased protection was based initially on the use of multi-layer perforated armour in place of conventional sloped armour; however, following release of details of Chobham armour under FMBT a further redesign was made to incorporate this technology. With Leopard 2 well advanced Germany wanted to delay the FMBT project; but the UK needed to continue to develop a replacement for Chieftain. UK also saw that programme timescales were being put at further risk due to continuing indecision regarding a common NATO tank gun. With the disagreement on timescales, work on the joint project was terminated in March 1977. The 10th and final Anglo-German FMBT Steering Group meeting convened in March 1978 at which it approved a 'lessons learned' document.

As stated, a Tri-National, Germany, UK and US project called the 'Trilateral Tank Main Armament Evaluation Programme', had been running in parallel to the UK/German FMBT programme. The aim was to select a new common NATO gun for FMBT, Leopard 2 and the M1. Three guns were assessed, the German 120mm smoothbore, the NATO 105mm gun firing new, improved, US ammunition and the UK experimental 110mm gun. The UK proposed the 110mm gun as it was lighter than



UK Twin Gun Casement Tank Scheme. This scheme was developed as a basis for illustrating the issues related to twin gun sighting layout and fire control performance rather than as a viable concept. (Crown Copyright MOD) the 120mm and easier to integrate. Comparative firing trials were carried out in the UK running from February to June 1975 in which each nation's gun fired around 1,000 rounds. The results of the technical trials were reported in August 1975; the performance of the 120mm and 110mm was shown to be superior to the 105mm. However, because the 110mm was less mature than the 120mm, it was rejected. This was despite the fact that it was more accurate than the 120mm at ranges greater than 1 kilometre and it was assessed that with further optimization it could match the penetration performance of the 120mm gun. Detailed studies were carried out at Chertsey into mounting all three guns types in both turreted and casement FMBT concepts. In the turreted concept the US 105mm gun was assessed to provide a solution 836kg lighter than that using the UK 110mm. However, the ammunition was one piece and only 38 rounds could be stowed compared with 40 110mm rounds. The total weight of the German 120mm was calculated to be 800kg heavier than the 110mm solution and although the same total number of rounds could be accommodated some locations could only stow KE rounds. It was also assessed that the larger calibre of the weapon increased the vulnerability of the mantlet area. In the casemate concepts the 105mm weapon saved 498kg over the 110mm solution and the 120mm was 779kg heavier.

MBT80 AND THE 4030 PROGRAMME



FV4211, the first tank fitted with Chobham armour. (Crown Copyright MOD)

Chertsey had been working on the development of Chobham (or Burlington) armour since the 1960s. The resulting armour solution consisted of flat armour ‘packs’ that needed to be mounted to the main hull or turret structure. This required a different approach to the vehicle design compared with the approaches used since World War II which were largely based on the use of welded or cast thick homogeneous steel armour. By the late 1960s the development of Chobham armour was well advanced and the decision was made to build a vehicle to demonstrate its integration and the practicality of resulting platform designs. This decision led to the build of FV4211 which was completed in 1971 and was the world’s first tank to be protected by the new armour technology. FV4211 was based on Chieftain components but with a new hull and turret structure. The hull structure made use of aluminium to keep the weight within acceptable limits. The feasibility and suitability of aluminium for MBT hulls had already been demonstrated on the ‘Test Vehicle Aluminium’ (TVA) demonstrator. It was testimony to the excellent Chertsey design office and workshops that the FV4211 demonstrator was built in only 13 months. Originally the vehicle was considered for an interim replacement for Chieftain in order to field Chobham armour as quickly as possible and a number of prototype vehicles were planned. Ten turret castings were made and work on nine hulls started but only one vehicle was completed. To ensure that a full set of Chieftain components was delivered for the first FV4211, ROF Leeds built a complete Chieftain vehicle using a rejected hull casting and this was delivered to MVEE for dismantling. The idea of putting FV4211 into production was dropped when work started on the UK/German FMBT programme, although it did form the basis of the ‘UK2’ concept developed for that programme. The single prototype continued to be used as a research platform. The very existence of Chobham armour, and hence FV4211, remained classified until the MOD issued a press release on 17 June 1976, when its existence was announced along with the statement that it would be fitted to the next generation of UK Main Battle Tank.

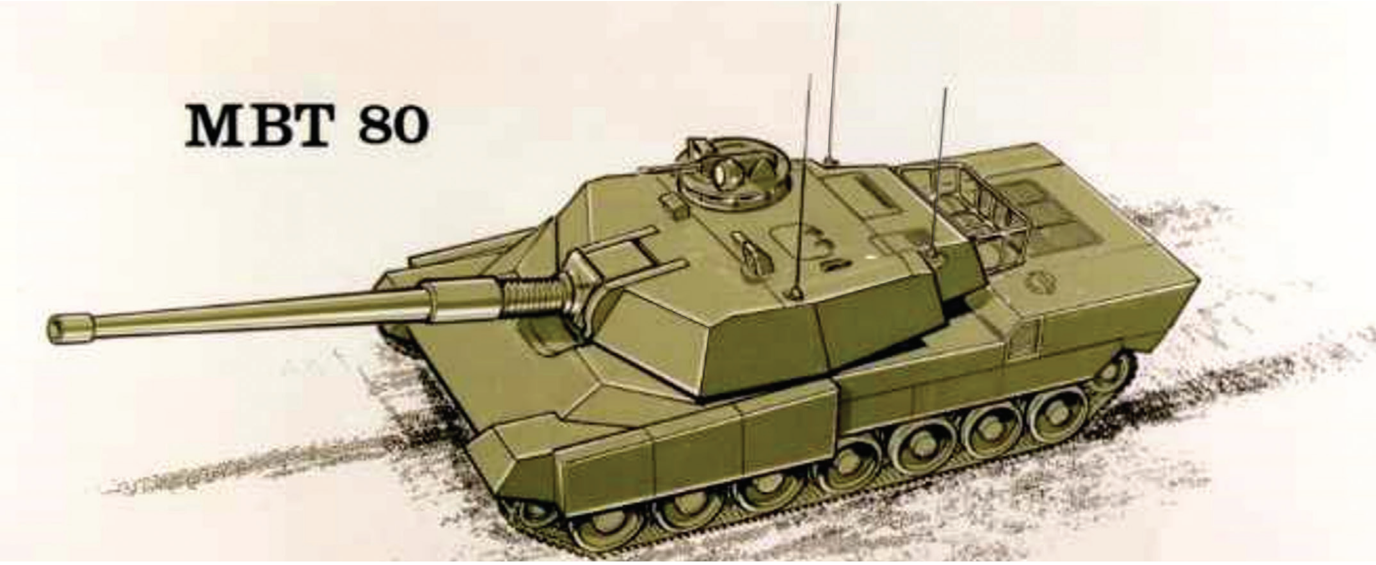
As FMBT was an international project, with the added complexities of joint decision making and work share, it was recognized from the beginning that it was likely to be subject to delays. This was borne out early in 1974 when, at the request of the Federal Republic of Germany, the concept phase was extended by 18 months. Hence the possible need for an interim vehicle was identified. In July 1974 a proposal was made for a project called 'Kinship' which would use the experience on FV4211 to design a vehicle with Chobham armour based on reworked Chieftains. Like FV4211, Kinship was to have an aluminium hull to keep the weight within acceptable limits. It was soon recognized that the so-called 'rework' was actually a very extensive exercise and would not be the low-cost option originally envisaged.

As the UK/German FMBT project was subject to further delays, and cancellation looked likely, MVEE worked with the Defence Operational Analysis Establishment (DOAE) at West Byfleet to explore the options for a UK national solution for the replacement for Chieftain. The list of options considered were:

1. Existing Chieftain Mark 5 run-on;
2. Reworked Chieftain Mark 5 with a Rolls-Royce V12 engine;
3. Reworked Chieftain Mark 5 with 110mm gun;
4. Reworked Chieftain Mark 5 with a Rolls-Royce V12 engine and 110mm gun;
5. New-build Chieftain Mark 5s with a Rolls-Royce V12 engine and 110mm gun;
6. Chieftain B: New-build Chieftain with RR V12 Engine and partial Chobham armour fit;
7. FV4222: New design with aluminium hull, 110mm gun and RR V12 engine;
8. UK1: Semi-fixed gun Class 60 vehicle with 110mm gun and RR V16 engine;
9. UK2: Conventional Class 60 tank with 110mm gun and RR V12 engine.

The FV4222 was a development based on FV4030, which is discussed below, and the UK1 and UK2 concepts were based on the UK preferred designs for the UK/Ge FMBT which in turn had been informed by the AFV for the 80s studies. DOAE issued the findings of the study in a report entitled 'Study of FMBT Options to Replace Chieftain' in February 1976. Of the concepts considered, UK2 and FV4222 were recommended for further consideration.

After the failure of the Anglo-German FMBT programme the US XM1, which developed into the M1 Abrams, was also considered as an option for the next UK MBT. This was rejected because it failed to meet



Artist's impression of MBT80. (Crown Copyright MOD)

the UK Staff Requirement; in particular the fire control capability was inadequate and, even though it incorporated Chobham armour technology, the protection had shortcomings. Hence, based on the studies to date and the lack of a suitable alternative from overseas, MVEE started work on what became known as MBT80. Following initial feasibility studies, the Project Definition (PD) phase was recommended by the Defence Equipment Policy Committee in June 1978 and initial work started on 1 August 1978. Ministerial approval to start full PD was given in October 1978. This was planned to be completed by March 1980 when ROF Leeds would start working with MVEE on the detailed design.

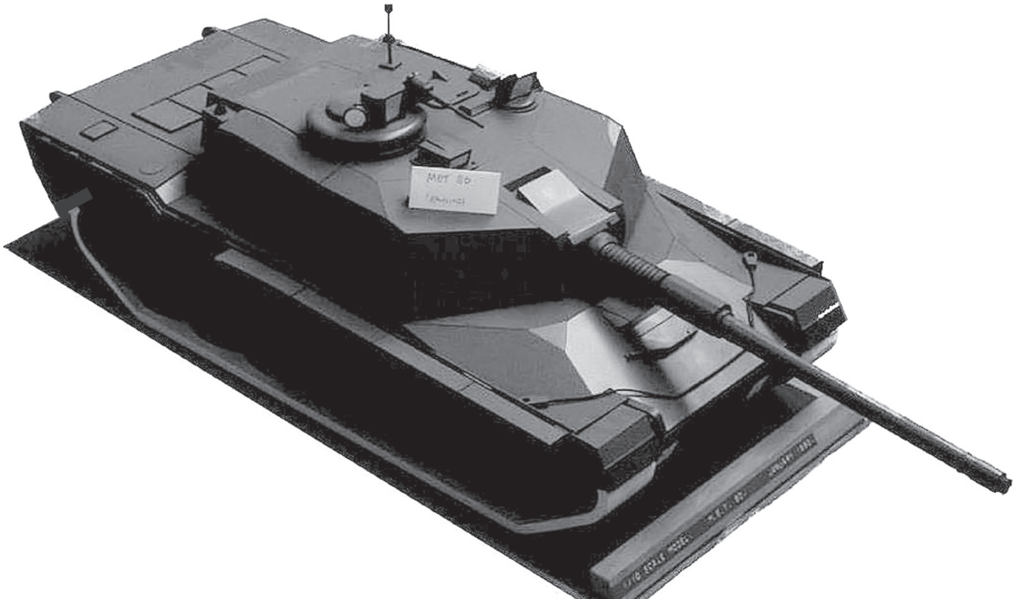
The financial planning was based on the production of 1,029 vehicles. £178m was approved for development, and production was estimated to be between £1,100m and £1,200m.

In August 1978 Prime Minister Callaghan sent a formal letter to President Carter in the US and Chancellor Schmidt in Germany inviting participation in the project. Although this approach did not generate interest in direct involvement in the project, a common concern about the Soviet tank threat resulted in a request from President Carter to develop closer links in studies of anti-tank systems in general.

Based on the recommendations from the Chieftain replacement options report the concept selected for MBT80 was a conventional four-man crew, turreted tank. It was, however, to have many advanced features; these included independently stabilized gunner's and commander's sights, a Thermal Imager (TI) with integrated rangefinder, digital gun and fire control with coincidence firing, a dynamic Muzzle Reference System, an advanced power pack and advanced electronics. The TI sight for MBT 80 was to be the STAMP (Sight, Thermal, Armoured, Periscope), with a CO2 laser rangefinder, hence called STAMPLAR. It was not a fully panoramic sight but could be traversed over an azimuth range of +/-90 degrees over the frontal arc of the turret. Due to its size the STAMPLAR unit, including its large cooling system, was to be mounted on the loader's side of the turret. A Chieftain was modified to represent the resulting internal intrusion in order to check that the loader could still operate effectively.

In order to support the design process, the MBT80 programme plan defined a number of system development rigs that were to be built, these included three turrets and two Automotive Test Rig (ATR) hulls, all of which were due to be completed by 1981.

One of the MBT80 turret rigs that was completed was a trials turret called the Fire Control Rig (FCR), built to support the development of the gun and fire control equipment. FCR used one of the FV4211 turret castings that had been manufactured but not used and it was initially mounted on a Chieftain hull using a spacer ring. The MBT80 gun and fire control system was being designed to provide at least a 33 per cent reduction in the engagement times achieved with Chieftain with IFCS. The FCR was the first MBT turret to be fitted with independently stabilized (free) sights for gunner and commander; on Chieftain the sights were mechanically linked to the gun. The 'Free Sight' system used a solution known as 'coincidence firing' where, once the aim point had



Model of MBT80 which was also designated FV4601. (Crown Copyright MOD) been determined, the gun was brought on to target and only fired when coincident with that aim point. This solution meant that only the sight mirrors had to be stabilized to a very high level of accuracy. The FCR also had solid state gun control equipment which ran at 56V (-/+28V) and used a digital data bus to link the main sub-systems.

Although the 120mm smoothbore weapon had been selected following the NATO assessment exercise project, MBT80 was to be fitted with a rifled 120mm gun. The main driver for this was the desire to be backwards compatible with the existing stocks of 120mm ammunition. The Royal Armaments Research and Development Establishment were challenged to develop an improved weapon design that used a shorter stiffer barrel, similar to the 120mm smoothbore, to improve accuracy but keeping the same penetration performance of a longer barrel. This resulted in a demonstrator weapon designated EXP28M1 which had a Crossley Pad split block breech. The new gun with new ammunition was intended to provide a 21 per cent increase in performance in comparison to the Chieftain L11. Another driver for retaining a rifled gun was the view that an HE round could be developed, enabling MBT80 to be used in an indirect fire role to compensate for a lack of artillery systems.

The aim of the first Automotive Test Rig (ATR1) was to demonstrate the viability of the proposed hull material and design. FV4211 had been built with an aluminium hull fabricated from material to MVEE Specification 1318, however, it was subsequently decided that material to MVEE Specification 570 would give better performance against large-calibre KE threats; hence ATR1 was built to demonstrate the feasibility of its use for MBT80. The driver's hatch was manufactured from 1318 aluminium as were the final drive mounts using components already manufactured in anticipation of further FV4211 vehicles. The selection of the hull material was fundamental to the whole MBT80 programme and so the build of the ATR1 was carried out as a priority activity with manufacture of the hull completed in April 1978. On completion it undertook stiffness testing at Christchurch before being delivered to Chertsey in May 1978 for assembly and testing. As with FV4211 it used Chieftain automotive components. Later the rig was used as a load for tank transporter trials before being scrapped.

The second rig, ATR2, was a 'transition-joint' hull with a steel front half and aluminium rear using 4030 running gear and power pack. The design logic behind ATR2 was to use steel at the front to provide an optimized structure for mounting the Chobham armour packs but aluminium at the rear to minimize hull mass whilst providing a stiff structure for the engine compartment. In addition, four 'side plate test rigs', which represented the rear left-hand side of a vehicle, were built to test mine resistance and the mounting of hydrogas units. One of these mine test rigs represented a transition-joint hull design. The other three, one of which used an available FV4211 rig, were fabricated using different grades of aluminium. As well as testing the mine resistance of the different materials the rigs were also used to investigate different solutions for mounting the hydrogas suspension units to ensure they could be removed and replaced if damaged. It was estimated that using aluminium for the hull sides, rear and belly would save around 3 tonnes. A final decision between an all-aluminium hull and a hybrid steel/aluminium hull was planned to be made during the PD phase when the results of trials of ATR2 were known. ATR2 is now at the Bovington Tank Museum where it is fitted with a casting for one of the proposed MBT80 turret test rigs; hence it is sometimes, but incorrectly, referred to as an MBT80 prototype.

Protection was given a high priority and the latest version of Chobham armour was to be fitted to MBT80. A 'Revised Threat Study' was carried out as part of PD to review the armour protection solutions and make recommendations for the final design. Following the review it was agreed that the target battle weight could be increased to 62 tonnes, rather than the original 54.5 assumed for the initial feasibility studies, thus allowing an increase in protection. The configuration of the main frontal armour was revised to increase protection levels and an appliqué armour scheme was designed for use on the sides. This could be removed to keep the basic training weight at 58 tonnes or be removed for transportation. Steel was selected as the main material for the turret structure because, as with the hull, it provided a better base for mounting Chobham armour. It was also decided that the turret structure would be manufactured using a new air-hardening cast steel which provided improved dimensional accuracy. This was important as considerable design effort had been expended to ensure that the casting was designed in the most effective manner to optimize both the structural performance and protection whilst minimizing weight. Three turret castings were manufactured for trials purposes and one of these was used to test the off-centre gun mount (25mm to the left) proposed during the design process; this is the turret casting now mounted on the ATR2 hull at Bovington.

A full-size wooden MBT80 turret mock-up was made to ensure that the ergonomics were satisfactory; it was fitted with space models of all the relevant sub-systems, including the NBC pack which hinged open to give access to the main electronic sub-system racks. MBT80 was to make significantly increased use of advanced electronics compared with previous designs and was designed to make use of the 'Modular Assembled Vehicle Installation System', or MAVIS standardized electronics racking system. The turret design had a traditional three-man layout but the commander was accommodated within the turret race ring, rather than on the sill as in 4030. This was achieved by moving the gun to the left by 25mm and angling the gunner 5 degrees to the left. MBT80 was the first tank that was being designed to accept the 95th percentile Royal Armoured Corps crewman at all stations which made minimizing the silhouette a challenge.[8]

Another full-scale wooden mock-up was made of part of the turret with a 'working' breech so that access to the ammunition stowage could be checked and the loading speed demonstrated (a rate of fire of 6–8 rounds/min was required). The trial was conducted using KE rounds of different lengths as the EXP28M1 gun was still under development and the length of the round not finalized. Loading trials were carried out using army crew members and inevitably resulted in a race to see who could be fastest. Damage to the rig due to over-enthusiastic loaders had to be repaired every evening to ensure the trials could continue the next day.

Analysis was undertaken of the engine options with mobility comparisons made between MBT80 with a V12 1,200hp diesel and V16 1,500hp diesel. The XM1, which was slightly lighter than the design weight of MBT80, was used to baseline the performance of a gas turbine option. In addition a 1,800hp version was modelled to understand the additional benefits of a more powerful engine. The options modelled were:

Chieftain (Baseline)	**750bhp**	**14.4bhp/tonne**
MBT80 V12	1,200bhp	21.8bhp/tonne
MBT80 V16	1,500bhp	27.3bhp/tonne
XM1	1,500bhp	28.3bhp/tonne
MBT80	1,800bhp	32.7bhp/tonne

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[8] The 95th percentile crewman defines the physical size envelope (anthropometrics) into which 95 per cent of armoured vehicle crew members will fit and be able to operate without constraints.

A 1,500bhp diesel was eventually selected with the decision formally endorsed in June 1979; however, rather than the proposed V16 unit it was an uprated version of the CV12 which at the time was the unit being used in the 4030/3 vehicles. Development of the TN38 gearbox, to match the proposed 1,500hp engine, was also started. The resulting power train would have given the vehicle a top speed of 65kph. Suspension was to be hydrogas with seven road wheels each side.

It was planned that nine prototypes would be delivered between April 1983 and October 1983 but none was completed. Production activities had been planned to start in 1986 with the first production vehicle being completed in September 1987 and delivery to operational units starting in 1989. The Royal Ordnance Factories could support a production rate of 200 vehicles a year, although there was potential to increase this to 240 vehicles and production was due to be complete by February 1994. Despite some unresolved technology issues, there was pressure from the Army to compress the programme and bring the in-service date forward. The desire for an earlier in-service date was driven by an assessment of Soviet tank trends and the view that by 1985 up to 80 per cent of the Soviet tank fleet would be T64s or T72s with a possibility that the projected T80 would also start to be fielded then. There was also concern that fielding of the M1 by the US and Leopard 2 by Germany would further emphasize the shortcomings of Chieftain.

In addition to the design work and test rig build and trials for the MBT variant some initial design work also started on an MBT80 based Armoured Recovery Vehicle, Project 3572. Other variants, such as bridge layers and recovery vehicle were postulated but not work undertaken.

Meanwhile MVEE had also been supporting Defence Sales in efforts to sell equipment to Iran. The establishment hosted a number of VIP visits including one by the Technical Advisor to the Iranian Minister of War on 24 November 1972 and the Iranian Vice Minister for War in March 1973. Initially efforts were focused on securing the sale of 800 Chieftains; however, although the Iranians wanted to buy Chieftain, they were interested in a vehicle with a more reliable engine, automatic transmission and Chobham armour. The FV4211 vehicle had already demonstrated some of the features they were looking for and a significant order for Main Battle Tanks was subsequently secured. The contract covered the delivery of vehicles, designated FV4030, in three phases, with each new phase providing significant improvements. The three phases were:

- FV4030/1: Chieftain Mark 5 with some minor improvements.
- FV4030/2: Shir 1: An improved Chieftain with:
  - The latest IFCS being implemented on British Army Chieftains;
  - A Rolls-Royce CV12 engine;
  - A David Brown TN37 Hydrostatic gearbox;
  - Redesigned hull rear and engine compartment to allow fitting of the new power pack.
- FV4030/3: Shir 2: A vehicle with a new hull and turret structure incorporating:
  - Significantly improved protection using Chobham armour;
  - The CV12/TN37 power pack;
  - Improved mobility through the use of hydrogas suspension;
  - A number of new sub-systems but with the gun and fire control system based on the latest version being fitted to Chieftain.

The size of the order was significant covering 193 Phase 1, 125 Phase 2 and 1,250 Phase 3 vehicles.

The main differences between FV4030/1 and the latest British Army versions of Chieftain were the use of automatic control for the TN12 gearbox, increased fuel capacity, improved mine protection and improved suspension damping.

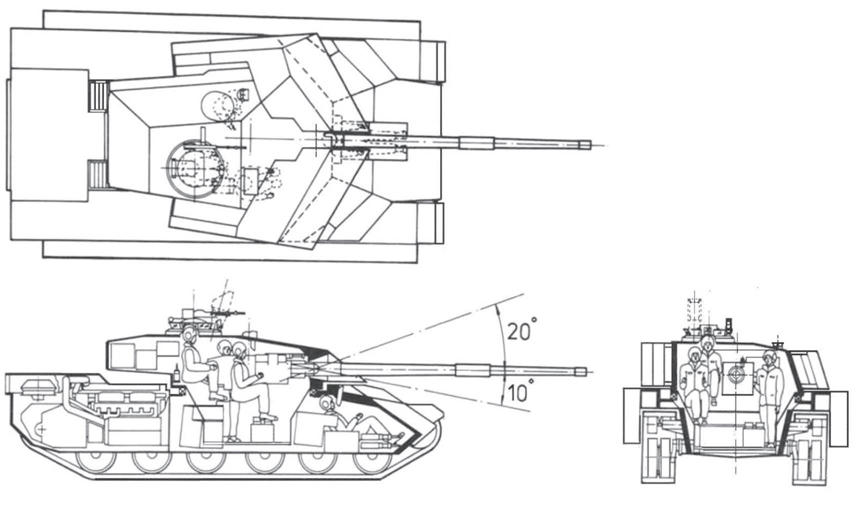
As well as IFCS and the new power pack, 4030/2 had a new commander's day/night sight (No.84 sight), a further increase in fuel capacity, Improved Bogey Suspension (IBS) and a new final drive and track. Three prototypes were made of 4030/2 designated V2A1, V2B1 and V2C1. The first prototype ran in January 1977 and the third was running by August 1977. V2C1 was transferred to the Armoured Trials and Development Unit at Bovington for trials with military crews from May 1978 to July 1979.

The FV4030/3, which was effectively a new vehicle, was developed within very short timescales compared with those normally associated with the development of complex armoured vehicles. Within five years of the development contract being signed, six 4030/3 prototypes were running and the first production vehicles had started to work their way down the production line at ROF Leeds. The Iranian order for Shir 2 placed the UK in the position of being the inventors of Chobham armour but possibly seeing the US (with the M1 Abrams) and Iran (with Shir 2) fielding it first.

The engine selected for Shir 1 and Shir 2 was the Rolls-Royce CV12 TCE which had successfully been run at 800hp in a Chieftain. The rating of 800hp was much lower than the power required for 4030 Phases 2 and 3, but within 18 months Rolls-Royce Motors had developed a 1,200hp version. The more powerful engine required a new gearbox and so the TN37 was developed; this was based on technology demonstrated in a Chertsey research gearbox called the TN16X. This was a hydrostatic steer gearbox which enabled the radius of turn of the vehicle to be continuously varied and not fixed by the gear ratio. The full design and development of the gearbox was undertaken by David Brown Ltd and, like the engine, was developed in a comparatively short timescale. Two automotive rigs were built for power pack and running gear development, called SPR4 and SPR5.

The Iranian order included Armoured Recovery Vehicles which were to be based on the Chieftain ARV and designated ARV(P). Project 4027 was for a Chieftain Mark 5 ARV fitted with a crane to lift the 4030 power pack and Project 4028 was for the same basic vehicle but fitted with the CV12 engine.

When work started on FV4030 a follow-up proposal to Kinship was considered which drew on the experience of FV4211, Kinship and FMBT. Again, this was proposed as an interim, or even alternative, solution to the UK/German FMBT and was referred to as the 'National MBT'. Outlined in a report issued in January 1975 it was a UK version of FV4030 and designated Project 4222. It was to mount a 110mm gun



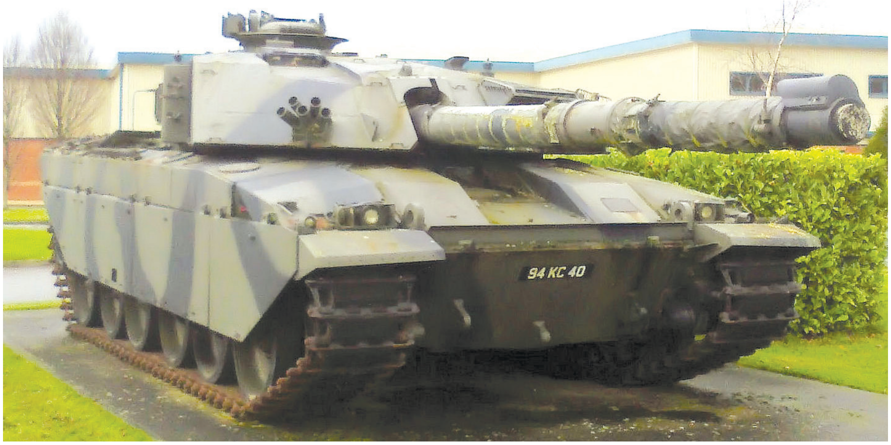
FV4222 proposed as a UK derivative of FV4030 to be used as an interim solution until the UK/German FMBT was developed. (Crown Copyright MOD) but be designed for this to be replaced with a 120mm gun if required. Like 4030 it was to be fitted with Chobham armour, a CV12 engine and hydrogas suspension, however, 4222 had a target design weight of 56 tons compared with the 60 tons of 4030. The weight reduction was to be partly achieved through the use of a combined steel/aluminium hull structure. The IFCS gun and fire control system developed for Chieftain was to be used and a night-fighting capability was to be provided by a Commander's Near Infrared Passive Night Sight and a Thermal Pointer. The proposal document included an outline development plan with detailed design and test rig build starting in 1975, prototypes delivered for testing in 1980 and 1981 and production starting in 1982.

Other data for FV4222 is as follows:

Crew: Four
Hull length: 7.9m
Width (without side armour): 3.51m
Height (excluding night sight): 3.02m
Ground clearance: 500mm
Track width: 650mm
Length of track on ground: 4.76m
Speed: 62.6kph

The proposal was not taken any further than this initial study phase.

By the beginning of 1979 all the 4030 Phase 1 vehicles had been manufactured and all but six had been delivered. These were retained in the UK for trials of the revised power pack installation. Then in March 1979 the change of regime in Iran meant the cancellation of the order. By this time all 125 of the Shir 1's (4030 Phase 2) had been built, but not delivered, and production of Shir 2 (4030 Phase 3) had just started. Nine hulls had been fabricated, two of which, along with two turrets, had been passed to the assembly line. The loss of the order presented significant problems to ROF Leeds which had transferred work on the Combat Engineer Tractor and Light Weight Gun to other Ordnance Factories in order to work on the Iranian order. The factory now had no orders and production of MBT80 was several years away. In October 1979 Jordan agreed to buy the undelivered Shir 1 vehicles, with some modifications, and ordered a further 149, thus ensuring ROF Leeds would be viable at least for the near term. The Shir 1 vehicles went into service in Jordan as



Early 4030/4 without a thermal imager. (Author's Collection)

the Khalid. The 4030/2 prototype V2C1 was reworked to the Khalid build standard for trials purposes and re-designated V2K1. The main changes to bring 4030/2 to the Khalid build standard were: fitting the latest version of IFCS – uprated to the ICSS standard – Tank Laser Sight and the No.84 Commander's Day/Night Sight, revising the stowage for 25 APDS and 34 HESH rounds, replacing the hydraulic starter motors with electric starters and a different radio fit. Deliveries of Khalid started in December 1981.

Some problems with track life were experienced on Khalid and a suitable representative test area in the UK was required to test the durability of redesigned tracks. The solution to the test site was use of an open basalt mine near to Frome in Somerset. At the time the mine was the largest in Europe and provided ample space for running the required thousands of miles of reliability testing.

CHALLENGER 1

Recently completed studies had recommended that the number of Main Battle Tanks allocated to BAOR should be increased. Although upgrades to Chieftain firepower were ongoing it was recognized that the armour protection was becoming inadequate against the latest Soviet tanks and, despite improvements to reliability, the power of the engine was unsatisfactory; hence the option of fielding more Chieftains was rejected. However, an option for 77 additional vehicles to enhance the war maintenance reserve was approved but overtaken by events. The opportunity to build 4030s, with minimum modifications, as a stopgap to address the issue of equipping BAOR until MBT80 was available, was quickly recognized. In April 1979 a draft GSR (3574) was issued. It was developed by Patrick Cordingley, who was then a major but went on to command the Challenger-equipped Desert Rats in the liberation of Kuwait. At this stage the vehicle, designated 4030/4, was referred to as the 'Cheviot'. A formal decision to consider fielding a UK version of 4030 was discussed by the Defence Equipment Policy Committee (DEPC) in March 1980 but it was agreed that industry should not be made aware of this decision and that any announcement would not be made until completion of the current PD work. In May 1980 Master General of the Ordnance (MGO) presented four options to the DEPC:

- Fielding of enough 4030/4 vehicles to equip one Division with MBT80 equipping the rest when that was available;
- Full fleet replacement of Chieftain by 4030/4;
- Half fleet replacement of Chieftain with 4030/4 and then development of a new MBT as an international project;
- Half fleet replacement with 4030/4 Mark 1 followed by development of a 4030/4 Mark 2 which aimed to meet the requirements defined for MBT80.

On 14 July 1980 there was a parliamentary statement that a new tank, to be known as Challenger, would be brought into service to equip four armoured brigades in BAOR. The £300m order for 237 Challengers exploited the opportunity to undertake a partial replacement of the ageing Chieftain fleet with a vehicle based on 4030/3 whilst making full use of the investments already made. As well as enhancing the BAOR until a full replacement of Chieftain could be fielded, it helped preserve around 10,000 jobs that had been put at risk with the loss of the Iranian order.

The requirement was compromised somewhat by what was achievable based on the existing 4030/3 design and within the time constraints imposed by the desire to keep ROF Leeds operating. There were, however, a number of required changes to the design. One of the most notable, and visibly obvious, was fitting the TOGS. The Chobham armour configuration was changed to further improve protection and ensure the vehicle fitted within the rail gauge constraints. There was a revised stowage scheme to take the new longer Armoured Piercing Fin Stabilised Discarding Sabot (APFSDS) round then being developed and the British Army standard stowage items (Complete Equipment

Schedule or CES). Other changes were made to the suspension and power pack to improve reliability. Although the gun and fire control system was based on IFCS hardware as used on Chieftain, it had improved software which introduced a stabilized aiming mark. The laser rangefinder was upgraded from a ruby laser to a neodymium-YAG laser to improve reliability and performance in poor weather. Full Treasury approval was given for the funding in October 1979 and a contract was placed with ROF in February 1980 covering detailed design and prototype build. The first prototype was delivered in September 1980 and seven were built altogether, designated V4C1 to V4C7. In addition, two other vehicles were used specifically to support TOGS development. The culmination of extensive trials and testing by MVEE and the ATDU was an exercise on Salisbury Plain in October 1982 in which a troop of four prototype vehicles undertook a four-day battlefield mission. It was reported that despite the official top speed of 56kph vehicles regularly exceeded 70kph. The resulting vehicle, 4030/4 (Challenger), was formally accepted for service on 14 December 1982 with the proviso that remaining issues with areas such as the engine generator drive, laser rangefinder and gearbox were to be addressed. The production order for 237 vehicles had already been placed in December 1980 and an additional 27 added to the order in September 1982. The first production vehicle was completed in December 1982 and formally handed over to the British Army on 16 March 1983, with the Royal Hussars being the first regiment to be equipped.

The decision to procure Challenger clearly had implications for MBT 80 and the same parliamentary statement announced that the MBT80 project would be cancelled; however, studies and technology maturation work would continue to support the development of a vehicle which, in the longer term, would replace the remaining Chieftains. By that time a number of contracts had been placed with industry covering different aspects of MBT80 development including with Alcan (aluminium plate), Barr and Stroud (thermal imager), Chubb (fire suppression system), Dunlop (brakes), David Brown (TN38 gearbox), Ferranti (laser rangefinder), Marconi (gun and fire control system) Microflow Pathfinder (NBC system), Pearsons (gun mount) and the Royal Ordnance Factories. Challenger 1[9] retained the

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[9] Although called Challenger the vehicle was subsequently called Challenger 1 with the start of the Challenger 2 project.

Challenger 1 tanks deployed for Operation *Granby.* (The Tank Museum, Bovington)

same basic layout as Chieftain, with a four-man crew, and had a significant number of sub-systems inherited from Chieftain especially associated with the weapon and gun and fire control system. It did, however, provide significant improvements in terms of protection and mobility. The significant increase in power-to-weight ratio, coupled with the excellent ride provided by hydrogas suspension, significantly increased cross-country speed and it was soon noted that across country it could keep pace with the Combat Vehicle Reconnaissance (Tracked), or CVR(T). Protection by Chobham armour was provided over the turret front and sides and over the hull front. Full technical details of Challenger 1 are given in Appendix D.

The vehicle was used very effectively by UK forces in Operation *Granby*, the liberation of Kuwait. Following that campaign, General Patrick Cordingley visited Chertsey to express his thanks for the support the establishment had given to the campaign. During a speech to staff he highlighted the performance of Challenger 1 and how it compared very favourably with that of the more complex and more expensive US Abrams tank. He noted that, aided with good support from the Royal Electrical and Mechanical Engineers, the vehicle had a very high availability through the 100-hour campaign and he still had 98 per cent of his vehicles operational at the end of hostilities. The high availability had allowed UK forces to undertake more extensive training than the US forces once in theatre and the resulting high readiness of crews and vehicles enabled them to successfully take on and defeat the best trained and best equipped elements of the occupying Iraqi forces.

The much longer range of Challenger 1 across difficult desert terrain compared with the Abrams also contributed to its success. Exploiting the vehicle's firepower and night-fighting capability resulted in many confirmed kills of Iraqi tanks including at night and at ranges beyond 4km. A testament to the tempo Challenger 1 provided came near the end of the campaign when the Desert Rats were ordered to occupy positions across the Basra Road before the planned ceasefire time. Due to what appears to have been a misunderstanding of time difference between UK and Kuwait, the Desert Rats were required to fight their way across difficult desert terrain and through enemy-held positions before the deadline; as a result they advanced over 40 miles in well under two hours. On another occasion, with reference to the Canadian Trophy gunnery competition, General Cordingley said 'Challenger is a tank built for winning wars and not competitions'.[10] A number of upgrades were made to the Challenger 1s specifically for the liberation of Kuwait, reflecting the offensive nature of the operation; these included additional armour protection on the hull front and sides, armoured stowage bins for the charges, external fuel stowage and a smoke-generating system. Many of the modification kits were developed at Chertsey and installed on the vehicles on arrival in Saudi Arabia.

Challenger 1 also saw service in Bosnia as part of the NATO Implementation Force (IFOR) and then Stabilization Force (SFOR).

In 1983, at the invitation of the government there, Challenger 1, along with Warrior, was successfully demonstrated in the United Arab Emirates (UAE) showing that it was able to cope with the terrain and environment for which it had been originally designed. A French AMX30S tank, 45 of which were in service in the UAE Army, was run alongside Challenger but unlike Challenger was not able to complete the mobility test course despite

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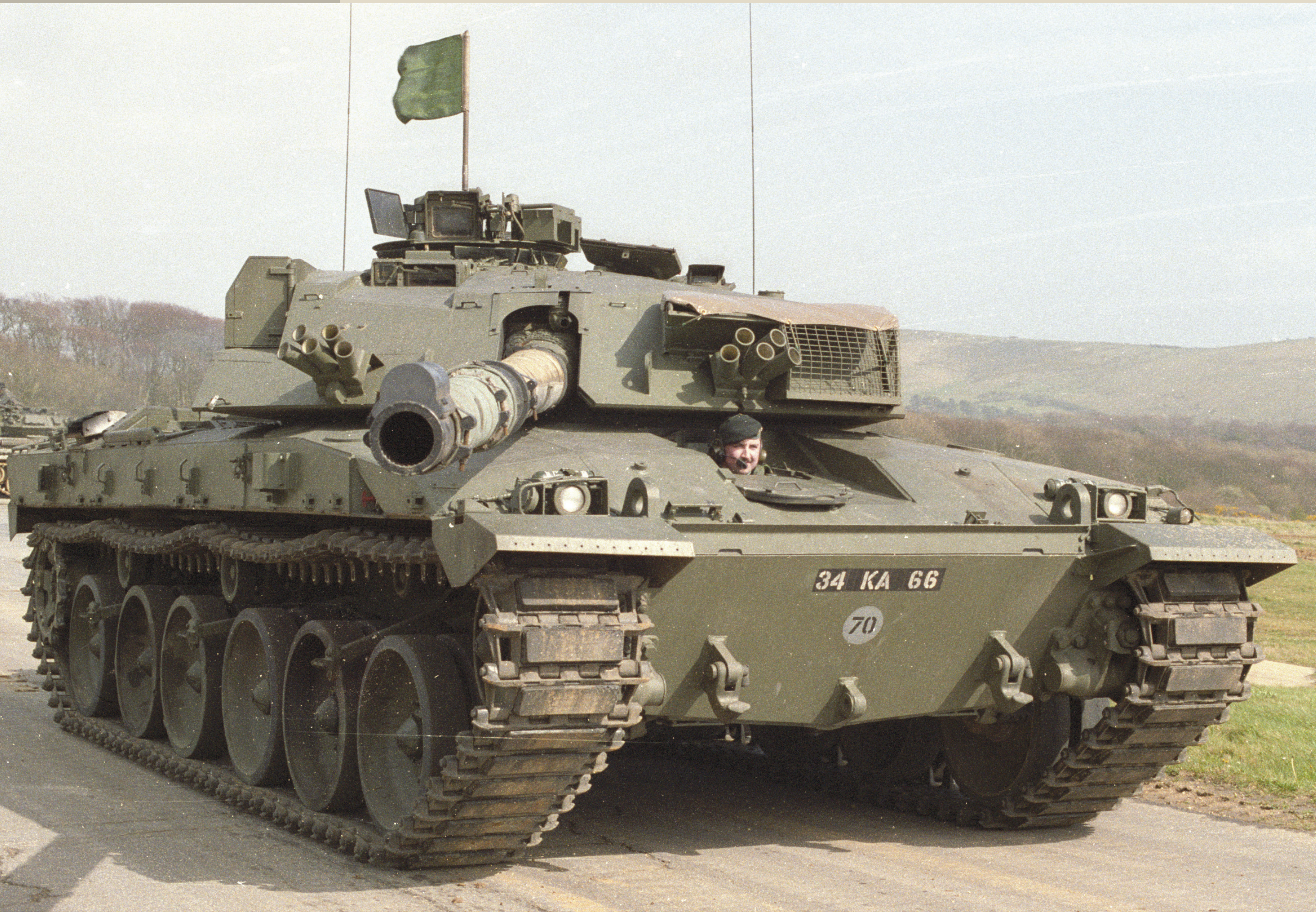
[10] The Canadian Trophy was a regular NATO gunnery competition which British Army participants in Challenger 1 tanks infamously came last in in 1985 and 1987.



Challenger 1 on the Lulworth firing range. (The Tank Museum, Bovington)

being a lighter vehicle. Availability of both UK vehicles was reported as being high during the trials which covered around 900km and any problems which did occur were assessed as being minor.

After being replaced by Challenger 2, 392 Challenger 1 tanks were supplied to Jordan where currently they are still in service.

Although the rapid introduction of Challenger 1 into service helped address the requirement to counter the growing threat from the current generation of Soviet T64 and T72 tanks, it was recognized that its performance fell short of that specified for MBT80. Challenger 1 retained the main weapon and gun and fire control system of Chieftain. MBT80 was being developed to have a probability of hit against a moving target at 2km of 56 per cent compared with 32 per cent for Chieftain. In addition, the time for a first-round engagement was to be reduced from 12.5 seconds to 7 seconds. As well as the limitation due to the inherited Chieftain weapon system, Challenger had a lower power-to-weight ratio, lower top speed and reduced protection over the sides compared with MBT80. Another concern was the lack of growth potential which strengthened the view that Challenger 1 should remain an interim solution.

To address known limitations of 4030/4 the Challenger Improvement Programme was initiated on 22 May 1980. This had the aim of bringing the vehicle up to the standard of that planned for MBT80. A draft General Staff Target (3875) was issued on 30 June 1980, following the formal cancellation of MBT80 two weeks earlier, with interim funding being approved on 24 July. The programme was to be in two phases each leading to changes being brought into production in December 1986 and mid-1989 respectively. The initial project was soon modified to have a less-ambitious programme of work which was undertaken to address both the Chieftain and Challenger fleets under what became called the Chieftain/Challenger Improvement Programme (CHIP). The key capability areas where improvements were to be sought through the CHIP programme were:

1. Automotive agility and manoeuvrability without loss of reliability;
2. NBC protection;
3. Firepower, including improved KE ammunition;
4. Gun and fire control to reduce engagement times and improve chance of hit against moving targets.

The automotive aspects included:

- An improved gearbox, the TN54;
- Digital Automotive System Control Unit (DASCU) – which replaced the Engine Control Unit (ECU) and controlled both the engine and transmission;
- Improved main engine and auxiliary generators with oil spray cooling for better high temperature performance;
- Hydraulic Track Tensioner (HTT);
- Double pin track.

User trials of the TN54, DASCU and HTT started on 3 December 1984 and, with the exception of the double pin track, the automotive upgrades were formally accepted by the Army on 21 November 1986. The improvements were initially used on the Challenger Armoured Repair and Recovery Vehicle (CRARRV) and later on Challenger 2 and the Trojan and Titan engineer vehicles.

Chertsey worked with Microflow Pathfinder, then at Farnborough, to develop the CHIP NBC filtration pack. This was three-quarters of the size of the existing No.6 Mark 2 pack but provided the same air throughput and had improved integrity. It was retrofitted to Chieftain and Challenger 1 and was later used on Challenger 2.

The firepower improvements led to the development of a new 120mm rifled gun, the L30. This was an evolution of the EXP28M1 that had been under development for MBT80 with the latest development gun designated the EXP32M1. Against the advice of the vehicle concept team at Chertsey, the barrel on the EXP32M1 was longer than that on the EXP28M1 and hence more flexible; this resulted in a weapon system that was less accurate. The gun and ammunition programme was called CHARM, Chieftain/Challenger Armament programme. The specification for the technical requirements was approved on 17 May 1983 and a contract for development placed on the Royal Ordnance Factory (ROF). ROF Birtley developed the rounds, ROF Bishopton the charge and ROF Nottingham the weapon. The CHARM programme had two strands covering ammunition and the weapon. Initially a new KE APFSDS round, the L23 was developed. This had a Tungsten Alloy penetrator and an aluminium sabot and was designed to be fired from both the existing L11 and the new L30 guns using the same propellant charge for both. This was followed by the CHARM 1 round, the L26, which had a Depleted Uranium penetrator and was the same mass as the L23; and like the L23 could be fired from either the L11 or L30 guns. Finally the CHARM 3 round, the L27, was developed specifically for the new gun. This was also a Depleted Uranium round but had a greater length-to-diameter ratio and so significantly better armour defeat performance. The L30 was the same calibre as the L11 and like the L11 the barrel was 55 calibres in length. It did, however, operate at a higher charge pressure giving a higher muzzle velocity. It also had a different breach design and was electro-plated with chromium to give a longer barrel life. The L30 gun was never retrofitted to Chieftain or Challenger 1 as originally intended but was fitted to Challenger 2.

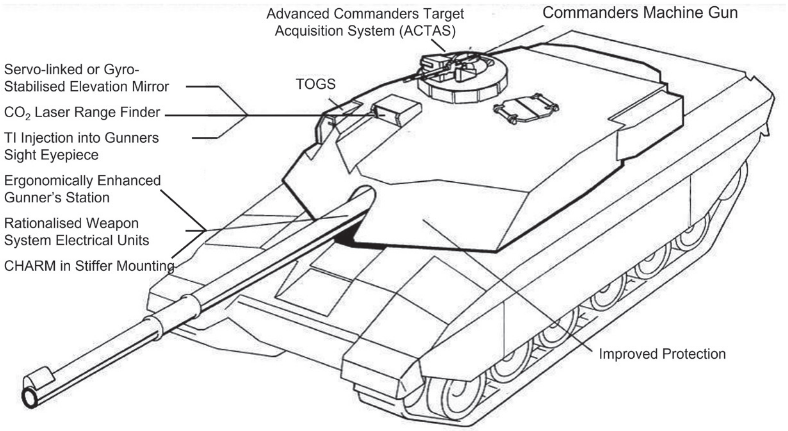
The improvements in the gun and fire control systems under the CHIP programme exploited the gun and fire control rig built as part of the MBT80 programme and further developed the free sight solution which was subsequently implemented on Challenger 2.

In addition to the CHIP programme Chertsey undertook studies into a Mid-Life Improvement Programme for Challenger 1. The studies were supported by work at ROF Leeds which reported in May 1983. Building on the CHIP programme the focus was on improvements to firepower, in particular addressing the limitations in the ICSS gun and fire control system. The studies considered both a cost constrained solution that was based on the existing CR1 turret and more extensive upgrades which required a new turret shell. All the options assumed that the base vehicle was brought up to 'CHIP' standards and the new CHARM main armament was fitted.

The 'cost constrained' upgrade solution, based on the existing turret shell, used much of the existing gun and fire control and sighting systems, but did involve replacing the gunner's sight with a new 'free' stabilized sight which was not limited by a direct mechanical link to the gun and was easier to use. Additionally, an improved display for the TOGS thermal imager was to be provided. The changes to the gunner's sighting system also freed up space which allowed some rearrangement of the gunner's controls to improve ergonomics. Protection was to be improved by using the latest version of Chobham armour.

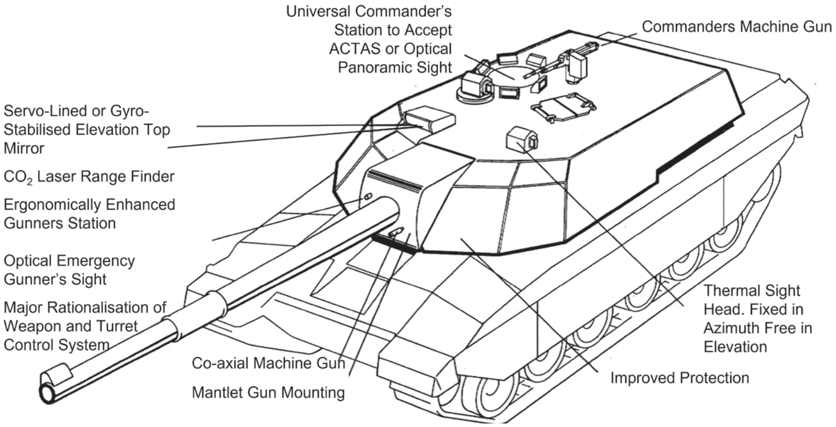
Options for an upgrade with a new turret shell included a conventional three-man turret or a two-man turret with autoloader and the designs had stretch potential to fit a larger-calibre gun in the future.

The concept for a three-man crew turret provided a new turret shell with a stiffer mounting for the main gun and built-in upgrade potential


Advanced Commanders Target Acquisition System (ACTAS)
Commanders Machine Gun
Servo-linked or Gyro-Stabilised Elevation Mirror
TOGS
CO$_2$ Laser Range Finder
TI Injection into Gunners Sight Eyepiece
Ergonomically Enhanced Gunner's Station
Rationalised Weapon System Electrical Units
CHARM in Stiffer Mounting
Improved Protection

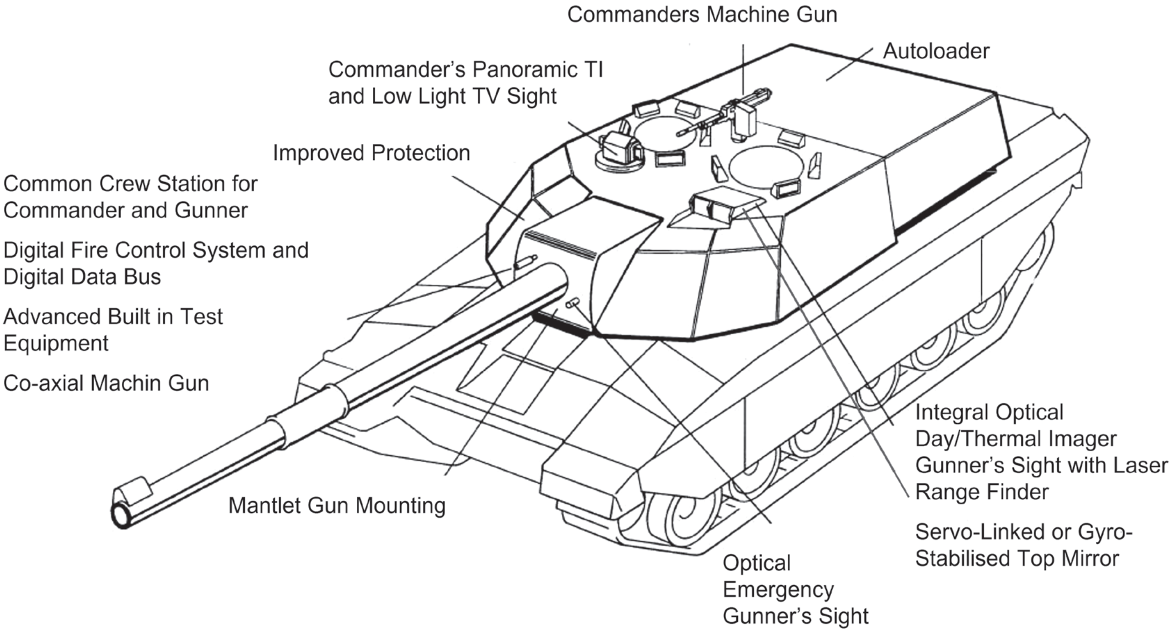
Challenger 1 MLI Concept 1; existing turret shell. (Crown Copyright MOD)

Challenger 1 MLI Concept 2; new turret shell, three-man turret crew. (Crown Copyright MOD)

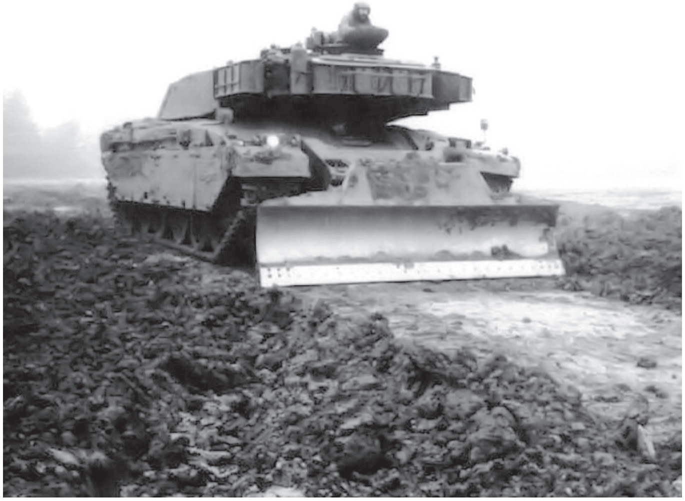

Universal Commander's Station to Accept ACTAS or Optical Panoramic Sight
Commanders Machine Gun
Servo-Lined or Gyro-Stabilised Elevation Top Mirror
CO_2 Laser Range Finder
Ergonomically Enhanced Gunners Station
Optical Emergency Gunner's Sight
Major Rationalisation of Weapon and Turret Control System
Co-axial Machine Gun
Mantlet Gun Mounting
Thermal Sight Head. Fixed in Azimuth Free in Elevation
Improved Protection

for a 140mm weapon. The gun and fire control and sighting system solution used many components from the existing Challenger 1 system and provided a capability similar to the 'existing turret shell' option; the main difference being moving the TI to just in front of the loader's position, hence improving armour protection over the frontal arc. Other improvements over Challenger 1 included the provision of an improved turret databus and electronics. The potential earliest in-service date of this solution was assessed to be in 1993.

Challenger 1 MLI Concept 4; two-man turret crew with autoloader. (Crown Copyright MOD)


Commanders Machine Gun
Autoloader
Commander's Panoramic TI and Low Light TV Sight
Improved Protection
Common Crew Station for Commander and Gunner
Digital Fire Control System and Digital Data Bus
Advanced Built in Test Equipment
Co-axial Machin Gun
Mantlet Gun Mounting
Optical Emergency Gunner's Sight
Integral Optical Day/Thermal Imager Gunner's Sight with Laser Range Finder
Servo-Linked or Gyro-Stabilised Top Mirror

A more advanced and more expensive three-crew turret option was also considered that additionally provided the commander with a stabilized panoramic sight with thermal and daylight TV channels. This along with further enhancements to the gunner's system would also support an automatic target detection and tracking solution.



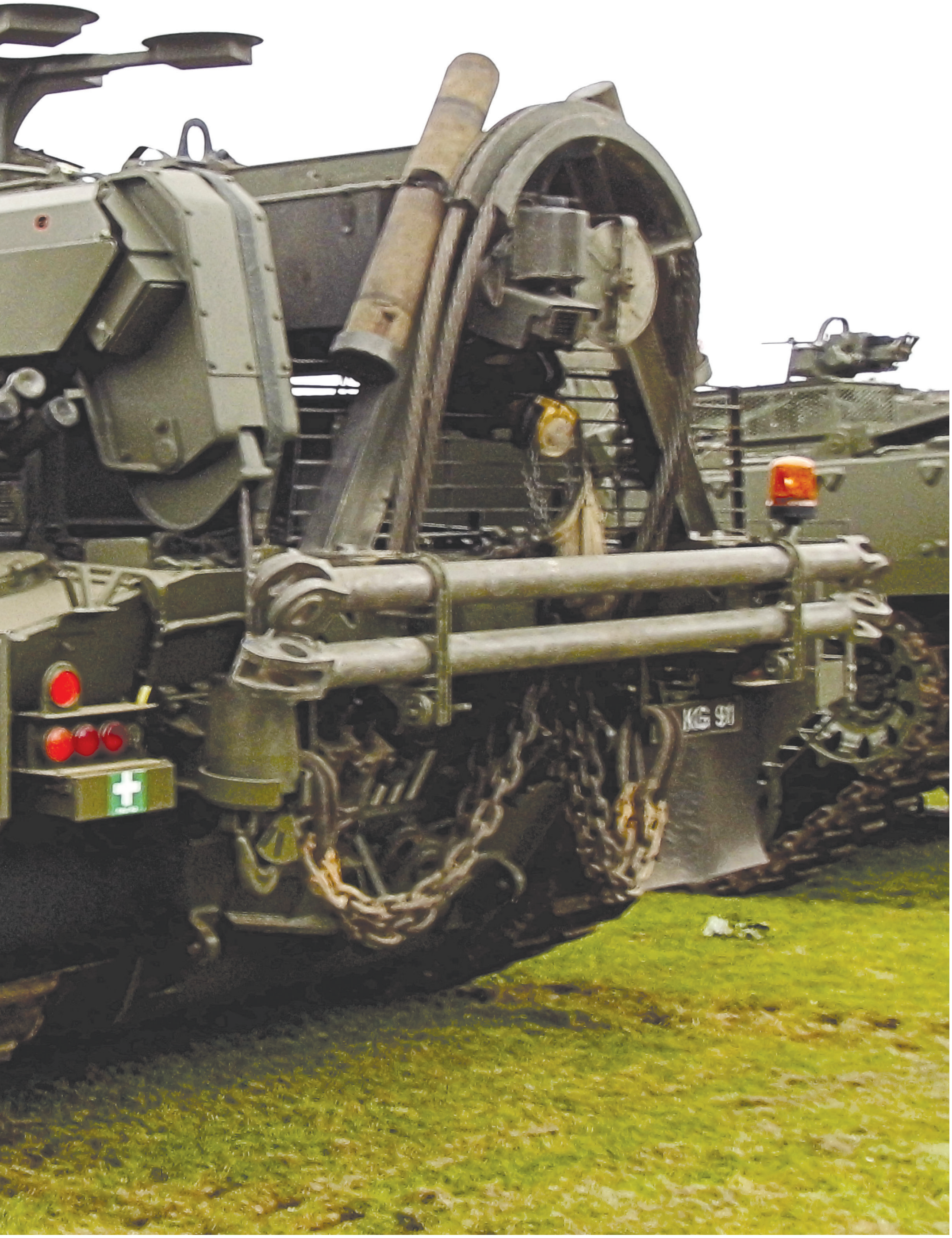
Challenger 1 with prototype dozer blade. (Crown Copyright MOD)

The two-crew turret concept utilized a bustle autoloader. The commander and gunner were positioned on either side of the gun and had a high level of commonality of controls and crew station functionality. The full redesign of the commander's and gunner's stations supported the introduction of an advanced electronic architecture solution with a high degree of redundancy and stretch potential. As with the more advanced three-crew turret crew solution the potential earliest In Service Date (ISD) of this concept was estimated to be in 1995.

It was assessed that the enhanced Chobham armour fit giving increased protection levels would have added around 2 tonnes to the weight of the vehicle.

CHALLENGER 1 VARIANTS

One variant of Challenger 1 developed under the direction of MVEE to enter service was the Challenger Armoured Repair and Recovery Vehicle. It was recognized early on that due to its faster speed and heavier weight Challenger 1 could not be supported by the existing Chieftain and Centurion Armoured Recovery Vehicles. In addition, the crane fitted to the FV434 repair vehicle could not lift the weight of the Challenger power pack. Therefore a General Staff Target, 3867, was raised for a repair and recovery vehicle to support Challenger 1 and SP70; a joint UK, German and Italian self-propelled gun being developed at that time. A feasibility study was carried out by MVEE and the report issued in August 1982 recommended a Challenger-based solution and defined the overall technical requirements. As an



Challenger Armoured Repair and Recovery Vehicle with additional armour fit. (Author's Collection)

Challenger training tank. (Crown Copyright MOD)

interim measure it recommended that Chieftain ARVs should be converted to ARRVs by the addition of a crane capable of lifting the Challenger power pack. The General Staff Target was formally endorsed in May 1983 and competitive PD studies were carried out by Vickers Defence Systems and ROF Leeds. Vickers Defence Systems was selected as the preferred contractor and a contract for full development and production was placed in June 1985. Initially the contract was for 30 vehicles, but this was later increased to 50. The first of six planned prototypes was rolled out in August 1987 and user trials started in March 1988. These were complete by May 1990 and were followed by the acceptance meeting in July 1990. The first production vehicle was planned to be vehicle number 7 (V7), however, some design changes were proposed to reduce the overall weight by 3 tons. The changes included a reduction in hull-side plate thickness and so V7 was used to demonstrate that hull integrity was maintained following the changes. V8 was the full production vehicle and vehicles V1, V2, V3, V6 and V7 were subsequently reworked to the production standard. The first four production vehicles were rushed straight from ROF Leeds to Saudi Arabia to supplement the Chieftain-based recovery vehicles supporting the Challengers deployed for Operation *Granby*. The vehicles, with nicknames Faith, Hope, Charity and Big Geordie, covered around 19,000 kilometres between them.

The Challenger ARRV has been deployed to support other operations including Operation *Telic* in Iraq and it has been extensively up-armoured and additional equipment added to bring it to 'Theatre Entry Standard'.

Another variant of Challenger 1 was the Challenger Training Tank (CTT) developed to the requirements of SR(L) 4009 for a driver training vehicle. This was a complete automotive hull, fitted with ballast in place of the special armour packs, but instead of the conventional turret it had a fixed 'turret' with no gun but large windows and seating for the commander/trainer and four additional personnel. The development contract for the CTT was placed with Vickers Defence Systems on 3 February 1988. The first trials vehicle was completed on 7 August 1989 and sent to ATDU for user trials on 7 November 1989. Following trials an acceptance meeting was held on 17 April 1990. In addition to the prototype a further 16 vehicles were procured, all for delivery in 1990.

As with Chieftain there was a requirement for some Challenger 1s in BAOR regiments to be fitted with a dozer blade. Chertsey placed a contract with Pearson Engineering Ltd of Newcastle to design a dozer blade and deliver two prototypes, these were initially used by Chertsey for technical trials before maintenance and performance trials with the user. The opportunity was taken to improve on the design used for Chieftain and produce a design which was cheaper and easier to fit. Challenger vehicles modified to be fitted with the blade required mounting points to be welded to the hull toe plate and provision for an electrical cable for the required 260 amps of power.

One interesting variant that never progressed beyond the initial concept stage was a launcher vehicle for the joint UK/French long-range 'Trigat' anti-tank missile. This vehicle would have had 12 ready-to-launch missiles and associated sighting systems on an elevating boom.

NEXT PAGES
Challenger in the experimental Multi Colour Digital Camouflage scheme. (Author's Collection)

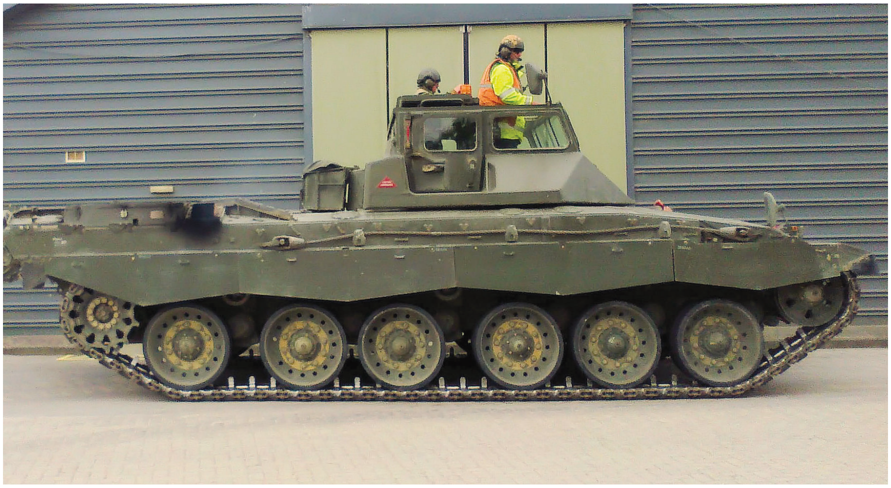
DS 48 AA

CHALLENGER 2

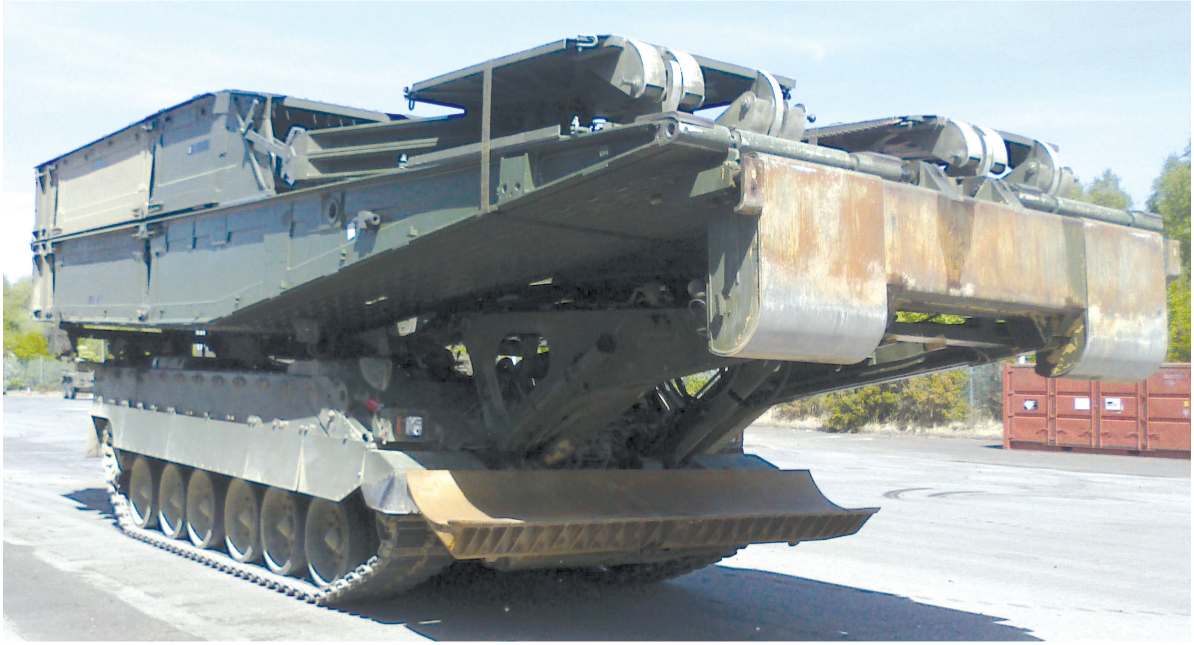
In 1982 the then Conservative government decided that the design authority for armoured vehicles should be transferred from Chertsey to industry. Chertsey continued to undertake research, testing equipment and provision of technical support to procurement activities, but no longer designed new vehicles for British Army use. This was the situation when the programme to replace the remaining 600 tanks in the Chieftain fleet, following the partial replacement by Challenger 1, was initiated. Called the Chieftain Replacement Programme it was limited to a competition between existing platforms with varying degrees of modification to meet the British Army requirements. The main role of Chertsey during the competition was to act as expert technical advisors to the Army, to support the development of the requirement, and to support the MOD procurement team when assessing the technical proposals. The full user requirement for Chieftain replacement, SR(L) 4026, was issued in November 1987. An important requirement of the Chieftain Replacement Programme was to provide improved turret ergonomics and gun and fire control equipment compared with Challenger 1, the turret systems of which had largely been carried over from Chieftain. The resulting competition was between the US Abrams, German Leopard 2 (Enhanced), French Leclerc and an improved Challenger, offered by Vickers Defence Systems (VDS). The assessment of the contenders started in January 1989 and was carried out in three phases with assessment reports being issued in September 1989, March 1990 and September 1990. This was followed by a three-month final selection phase. In addition to the assessment of the four contenders, the MVEE Concepts Branch developed a 'benchmark' design, called the Evolutionary National Tank (ENT), to illustrate what could be achieved using mature technologies but starting from a clean sheet of paper. This design would have been significantly more survivable than any of the vehicles offered but would have required development from scratch. The ENT is described in more detail in a later section.

To mature the solution for an improved Challenger a development contract was placed on VDS. The contract also covered an improved 120mm gun and ammunition – CHARM 3. The hull of the VDS vehicle was similar to that of Challenger 1 but with the automotive upgrades developed under the CHIP programme. The turret was a new design which was similar in concept to that of Challenger 1 but it exploited work carried out under the MOD gun with its fire control research programme at Chertsey and complementary work by VDS which had resulted in the gun and fire control and other sub-systems on the VDS Private Venture Mark 7 tank. The VDS contract covered the delivery of nine prototypes, a weapons test and integration facility and armour rigs.

The competition was won by the VDS-improved Challenger which was assessed to be superior to the competitors particularly in the area of survivability. The vehicle entered service in 1998 as Challenger 2. In addition to the improved, state-of-the-art, gun and fire control system it had an improved version of Chobham armour, improved turret ergonomics, the more effective L30 120mm gun and associated ammunition, including the effective CHARM 3 round. In addition to the TN54 gearbox, improved suspension and other upgrades to the hull developed under the CHIP programme there were around 150 other design changes to improve hull system reliability and maintainability. One area where Challenger 2 did make significant advances compared with Challenger 1 and other contemporary vehicles in the competition was in the area of signature management. This was achieved by exploiting the output of Chertsey research and expertise, and Vickers Defence Systems directly funded the Chertsey experts to support their design effort. Proposals were made to increase the power of the engine from 1,200hp to 1,500hp which would have also required upgrades to the gearbox and suspension designs, but this was not taken forward.



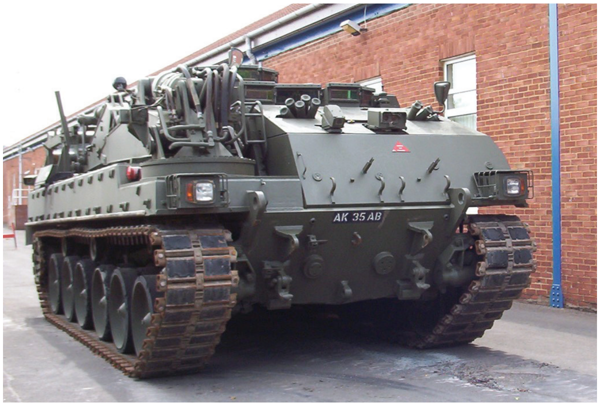
Challenger driver training tank. (Author's Collection)



Titan, Challenger 2-based bridge layer. (Author's Collection)

The initial order which covered the development and delivery of 127 vehicles, to replace remaining Chieftain tanks, and 13 Driver Training Tanks (DTTs) was placed on 28 June 1991. User trials of prototypes were undertaken at ATDU between September 1993 and February 1994 and the acceptance report issued on 5 April 1994. The prototypes were found to be acceptable subject to minor changes to improve the thermal imager display and a solution for quicker refuelling. The intention at that time was to update the existing Challenger 1s, either with the new gun as fitted to Challenger 2 or even with brand new turrets to the Challenger 2 standard. The drive from the Treasury to reduce the size and cost of the army following the collapse of the Soviet Union resulted in a decision to reduce the Royal Armoured Corps from 13 tank regiments to eight and the number of tanks per regiment reduced from 50 to 38; hence later in 1994 the decision was made to move to an all Challenger 2 fleet and replace the Challenger 1s, thus a further order for 259 vehicles and nine DTTs was placed. The only other nation to order Challenger 2 was Oman which has a fleet of 38.

Trojan Challenger 2-based heavy engineering tank. (Author's Collection)



Challenger 2 was successfully deployed to the Balkans as part of the NATO Kosovo Force (KFOR) and was used in action during the invasion of Iraq. With additional armour packs using solutions developed at the Defence Science and Technology Laboratory, Challenger 2 proved to be very well protected with some vehicles receiving multiple RPG hits when on patrol with no significant crew injuries or significant damage to the vehicles.

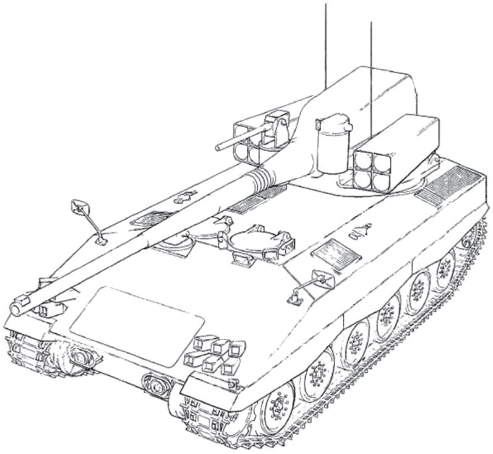
VDS, which was later taken over by BAE Systems, went on to develop two engineer variants based on Challenger 2, a bridge layer (Titan) and a general purpose engineer variant (Trojan). These replaced the Chieftain-based bridge layer and AVRE, the mobility of which was totally inadequate for keeping up with the Main Battle Tanks they supported.

In 1993 Chertsey initiated work with VDS for a trial fit of a 1,500hp Europack power pack with an MTU engine and Renk gearbox under a project called 'Exmouth'. This was a research-funded activity to investigate the operational benefits of increased power along with the impact on other components and fuel consumption. A contract for the demonstrator was placed and a project start-up meeting held in May 1993. Modifications to the vehicle to accept the new power pack included engine decks, heel plate, engine mounts, louvres, driver's controls and brakes. The vehicle was delivered to the MOD in December 1994 by which time the modifications were complete and the vehicle had carried out 398km of shake-down trials. The vehicle was used by VDS as a sales demonstrator and was called Challenger 2E or Desert Challenger.

Soon after Challenger 2 was accepted into service studies started into potential upgrades. In 1996 Chertsey undertook a study into options for a Challenger 2 Mid-Life Improvement Programme. Analysis was undertaken of five concepts covering a range of upgrades and hence costs. The concepts from most expensive to least expensive were:

1. **CONCEPT A:**
    - Mobility improvements including Europack, new track and improved running gear and weight-reduction measures including new turret structure.
    - Firepower: Improved 120mm gun with a gun-launched anti-tank guided missile (GLATGM) capability, panoramic day/thermal sight and automatic target detection and tracking.
    - Fightability: Improved power system and battle management system.

   - Survivability: Improved armour, Defensive Aid Suite and improved mine protection.
2. **CONCEPT B:**
   - As for Concept A but without the new turret structure.
3. **CONCEPT C:**
   - As for Concept B but with improved engine only and not the Europack.
4. **CONCEPT D:**
   - As for Concept C but with the improved 120mm gun and no armour upgrades.
5. **CONCEPT E:**
   - As for concept D but with no running gear upgrades, limited improvements to power system and no Defensive Aid Suite.

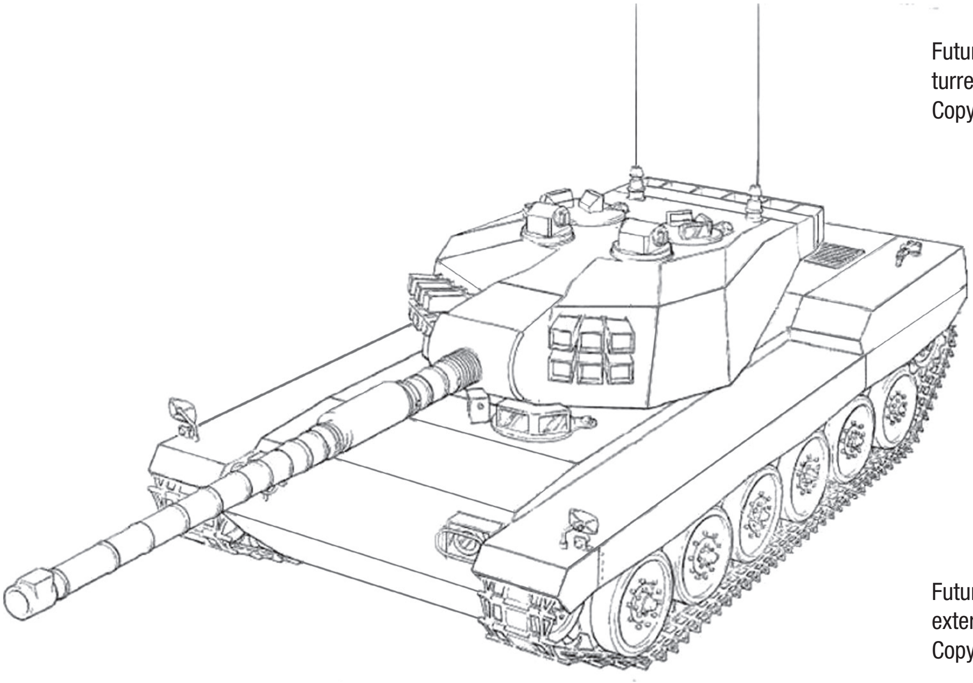


Future Tank Concept C, external gun and missile concept. (Crown Copyright MOD)

The cost span of the options was significant with Concept A estimated to cost nearly six times that of Concept E. Mobility and vulnerability analysis of the concepts was undertaken along with operational analysis using war gaming tools to demonstrate the effectiveness of the proposed improvements; however, none of the proposed improvements was taken forward at that time.

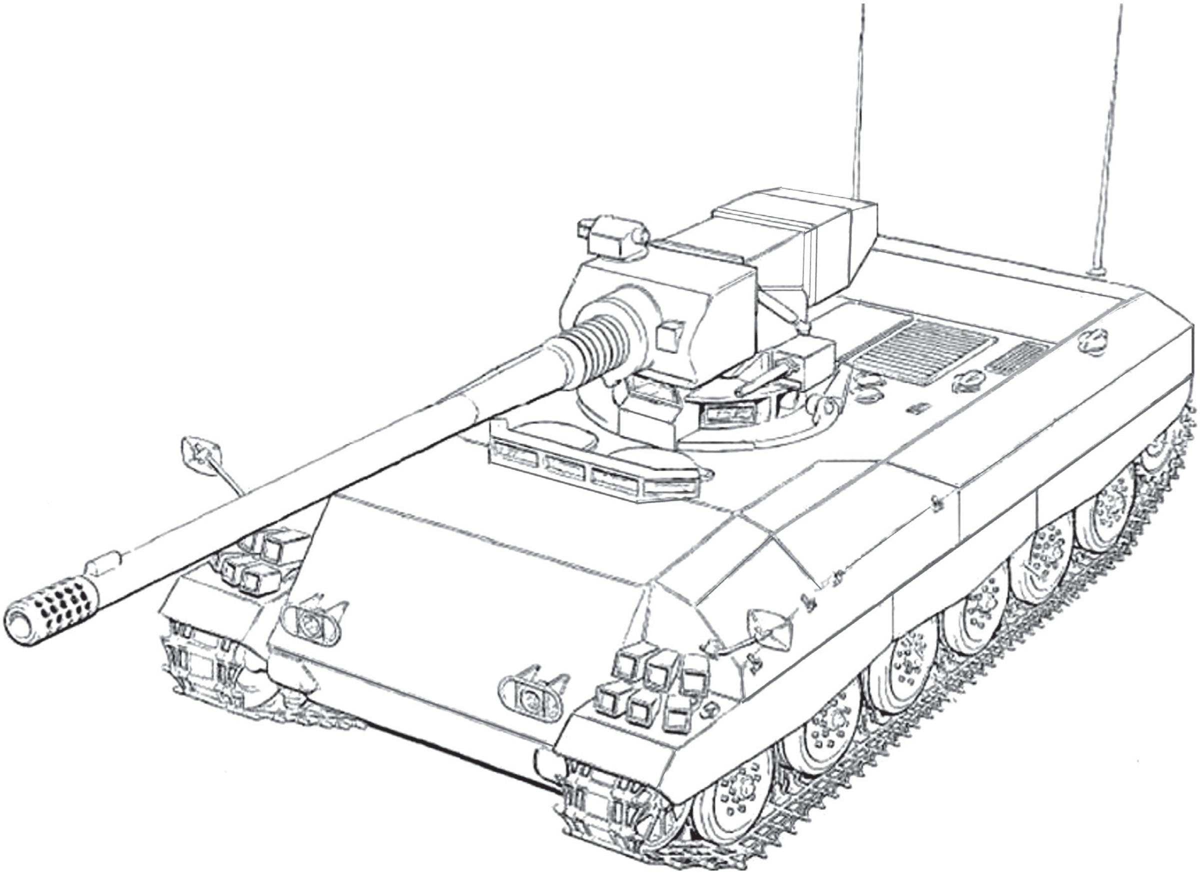
In December 1999 a Challenger Pre-Planned Product Improvement study was issued. This study considered a number of phased incremental upgrades rather than a single Mid-Life Improvement Programme. Technologies for the staged upgrades were placed into four 'Technology Insertion Groups' or TIGs to be implemented after 5, 10, 15 and 20 years. These were:

- TIG A: Radio upgrades, Combat Identification System and a Defensive Aid Suite;
- TIG B: Improved ammunition, auto-tracking system and more advanced Defensive Aid Suite;
- TIG C: Survivability upgrades and improved battle management systems;
- TIG D: Not defined but exploited to exploit new technologies developed in support of future tank projects.

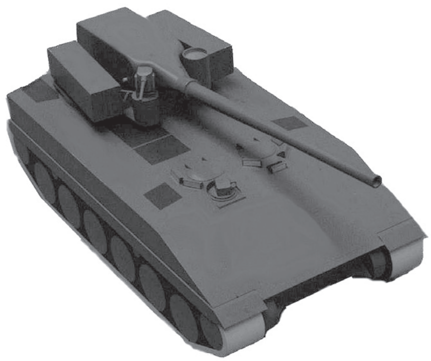


Future Tank Concept A, small turreted tank. (Crown Copyright MOD)

Future Tank Concept B, external gun tank. (Crown Copyright MOD)



FUTURE CONCEPT STUDIES



Scale model of Future Tank Study Concept C. (Crown Copyright MOD)

As far back as 1976, even as the MBT80 project was running, thoughts were turning to what would replace that vehicle and MVEE carried out a short study in conjunction with RARDE into what was designated MBT95. When MBT80 was cancelled and the decision made to field Challenger 1 it was agreed that some work on technology maturation would continue under the Future Tank Programme. The technology maturation work was underpinned by the development of concepts.

MVEE undertook a more detailed study into the longer-term requirements for a Main Battle Tank to be fielded in 1995. Findings were presented at a conference hosted at Chertsey on 14 July 1981. This considered a range of options including CHIP, the Challenger 1 Mid-Life Improvement concepts, a restarted MBT80 or a totally new vehicle. A focus of the study into new vehicles was the benefits that a smaller size of vehicle gave in terms of survivability, hence the design work sought to develop concepts that were the same size as, or even smaller than, T72. As well as size, weight was a key driver, 50 tonnes was seen as the maximum target weight, although 40 tonnes was given as a stretch target. As well as the desire for a much lighter Main Battle Tank 40 tonne was considered a more appropriate weight for a family of vehicles. Ideas to reduce the size and weight compared with Challenger included either having only two men in the turret and using an autoloader, or by having an external gun with either a two- or three-man crew in the hull. Concepts reviewed included:

- Turreted tanks in the range 50–65 tonnes with engines from 1,000hp to 1,750hp;
- Turreted tanks in the range 40–50 tonnes with engines from 800hp to 1,350hp;
- External gun tanks in the range 40–50 tonnes with engines from 800hp to 1,350hp;
- Casemate tanks in the range 40–50 tonnes with engines from 800hp to 1,350hp.

In order to meet the 1995 in-service date it was recognized that refinement of a down-selected concept would need to start in 1984, followed by project definition in 1986 and full development starting in 1988. To meet these timescales, Director General Fighting Vehicles and Equipment placed contracts in July 1982 with three consortia which were led, respectively, by Vickers, Alvis and ROF Leeds who were tasked to develop future tank concepts. A goal in developing the concepts was to identify the key technologies required for future vehicles and hence inform research and demonstration activities. As ROF Leeds did not have a concept cell they included the MVEE Concepts Branch as the core of their team and the output of the work was reported in April 1983 in the 'Future Tank Concept Study Report'. The Chertsey team generated three concepts:

Concept A: Designed as the smallest possible conventional turreted tank with a weight limit of 50 tonnes. Mounting a 120mm gun it had a three-man crew and a carousel autoloader. The engine was a 1,250hp V12. Overall dimensions were: length 9,620mm, height 3,540mm and width 2,400mm.

Concept B: Designed to maximize crew protection within a 50-tonne weight limit. It was a 120mm external gun concept with a three-man crew in the hull and a 'chaser' autoloader. The 'chaser' autoloader collected ammunition from a compartment at the rear of the hull into a loading tube which then rotated to align with the rear of the turret in order to load the round from beneath the armoured housing around the breach. The system required the gun to be horizontal when the round was loaded but only took 5 seconds to load the first round and a maximum of 5.3 seconds to load subsequent rounds. Twenty-four rounds were stored in a belt magazine in the hull and solutions for a secondary magazine in the 'turret' were considered. The main sight was a stabilized panoramic TI and Day Camera unit mounted above the gun housing. The use of a stabilized sighting system meant that the requirement to bring the gun to the horizontal to load did not impact on target engagement times. The proposed engine was a 1,200bhp V8. Overall dimensions were: length 9,200mm, height 3,370mm and width 2,820mm.

Concept C: Designed as a high-agility tank with a weight of 40 tonnes. It mounted a 105mm external gun and two packs of four

> long-range TRIGAT ATGW each side of the external gun mounting. It had a crew of two and was powered by a 1,200bhp gas turbine. The main sighting system consisted of stabilized panoramic thermal and daylight cameras mounted in a housing on the external gun-armoured structure. The turret was mounted towards the rear of the vehicle with ammunition stowed in a rotary magazine underneath allowing replenishment through rear hull doors. Overall dimensions were: length 6,500mm, height 3,359mm and width 2,900mm.

Further refinement was undertaken on Concept A with the output feeding into a revised concept that was called the 'Small Turreted Tank' concept.

Meanwhile the requirements for a new Main Battle Tank were endorsed by 'Project Foresight'. This was a study into the evolving threat from Soviet tanks and ATGW and was focused on the battlefield of 1995. A project report was issued in January 1984. This recognized the ongoing need to enhance protection levels whilst at the same time increasing lethality to defeat the latest Soviet tanks. In terms of technology it focused on the need to exploit the operational advantages that came from the use of thermal imagers and advocated the use of automatic target detection systems.[11]

The Future Tank Study identified a number of technology areas where research and risk reduction were required; these were addressed by two programmes. The first, called the 'Component Technology Demonstrator Programme' (CTDP); this included work on use of a gas turbine engine, signature management, autoloaders and sighting systems. The second, called the Operation Demonstrator Programme (ODP), focused on user aspects of new technologies.

In order to understand use and performance of modern gas turbine engines the CTDP funded the installation of a state-of-the-art engine in a Chieftain; with the actual integration work being undertaken by ROF Leeds. Following the original installation of a gas turbine engine in a Conqueror hull in the 1950s, the idea of using gas turbine engines in armoured vehicles had been revisited a number of times. In 1969 a 140hp Rover gas turbine was trialled in an FV432 and in the 1970s a proposal

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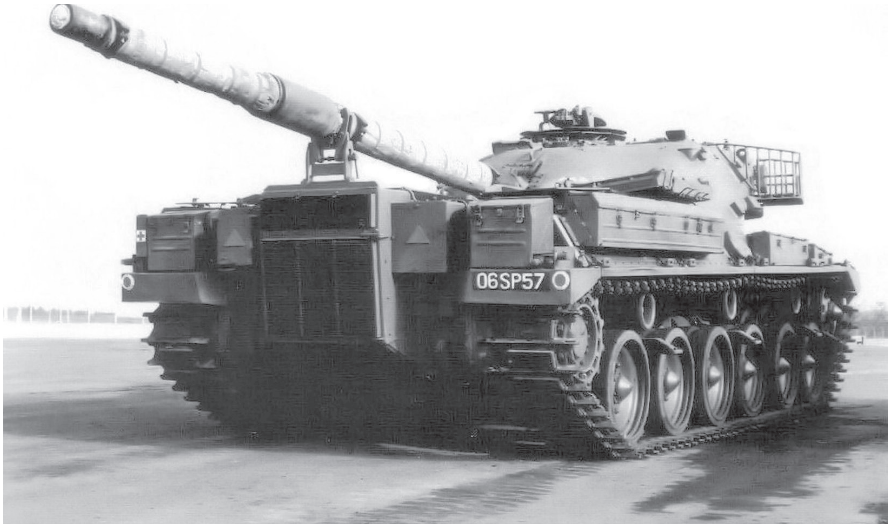
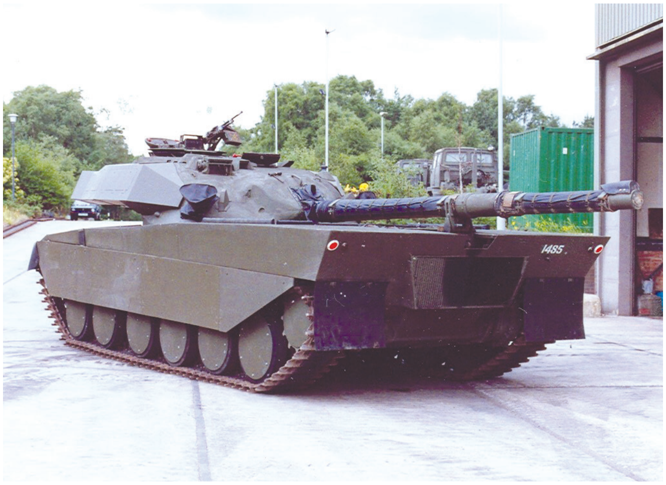
[11] The experts at Chertsey used the term 'aided' detection systems rather than automatic as they are not 100 per cent effective.



Rear view of Chieftain with gas turbine engine. (Crown Copyright MOD)

was made to test the AGT1500, as used in the US M1 Abrams tank, in a Centurion. The engine selected for the CTDP demonstrator was the Garrett Turbine Engine Company (GTEC) GT601. This was selected because, unlike the AGT1500, it had been developed specifically for automotive use and with an installed power of 638hp it was similar in output to the L60; hence it could use a modified TN12 gearbox and the existing drive sprockets. Performance benefits were expected because the engine gave better low-speed torque than the L60 and was lighter. The installation of the engine had been completed by February 1987 and the vehicle undertook some limited testing at ROF Leeds; which by this time was owned by Vickers Defence Systems. It was then delivered to Chertsey where it had a short life as it was found that the power pack could not survive the shock loads due to gear changes. Following a catastrophic failure of the engine, various schemes for improving its life were discussed but never taken forward as Garrett stopped supporting development.

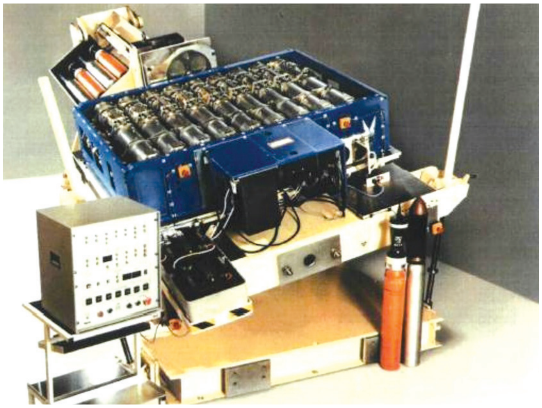
More successful was the Signature Classification and Reduction (SCAR) programme. This developed and demonstrated a number of signature reduction technologies and techniques. Initial demonstrations were carried out using appliqué measures fitted to Chieftain and Challenger 1 tanks. Following the success of these a Chieftain-based Signature Integration Demonstrator (SID) was built at Chertsey. Unlike previous demonstrators the build of SID was not constrained by the need to return the vehicle to its original state following trials and demonstration; hence the modifications could be more extensive.



Signature Integration Demonstrator with turret in gun crutch. (Crown Copyright MOD)

Although some low signature demonstrators had already been built in other countries this was the world's first fully functional stealthy tank; retaining the full fighting capability of a Chieftain. SID successfully reduced the radar, thermal and acoustic signatures of the vehicle, although drivers reported it was harder to drive as they could not hear the engine! Two SID vehicles were built, funded by a weapon system development programme, and they were intended to be used as representative future targets for testing the sensor and targeting system. When Chertsey was closed down one of the SID vehicles was stripped down to its primer ready for disposal and is now owned by the Norfolk Tank Museum where the modified hull exhaust area is the only evidence of its previous incarnation. The other had its sensitive materials and technologies removed and is now at the Bovington Tank Museum.

The CTDP autoloader studies focused on solutions for a bustle autoloader as a carousel autoloader was constructed and demonstrated as part of a parallel research activity. A bustle autoloader demonstrator was designed and built, the target size of which was defined by the space envelope of the Challenger 1 turret bustle. It was required to hold 20 ready rounds with a mix of APFSDS and HESH and be able to automatically load at a rate of one round every six seconds. The main aim of the project was to demonstrate that such an autoloader would be reliable and safe to operate. The system consisted of tubes on a conveyor belt to hold the rounds and had an optical round identification system and a ribbon rammer. A 'breach door' between the bustle and the main crew compartment automatically opened to load rounds but otherwise was closed to separate the crew from the ammunition. The gun was brought to the horizontal position for loading and the loading process was microprocessor controlled. Replenishment of rounds was intended to be through doors on the rear of the bustle. The demonstration loader was designed and manufactured by Fairey Hydraulics Ltd and then delivered to Chertsey for acceptance testing. The loader was mounted on a tilting platform to allow testing



Future Tank Bustle Autoloader on tilting platform for acceptance tests. (Crown Copyright MOD)

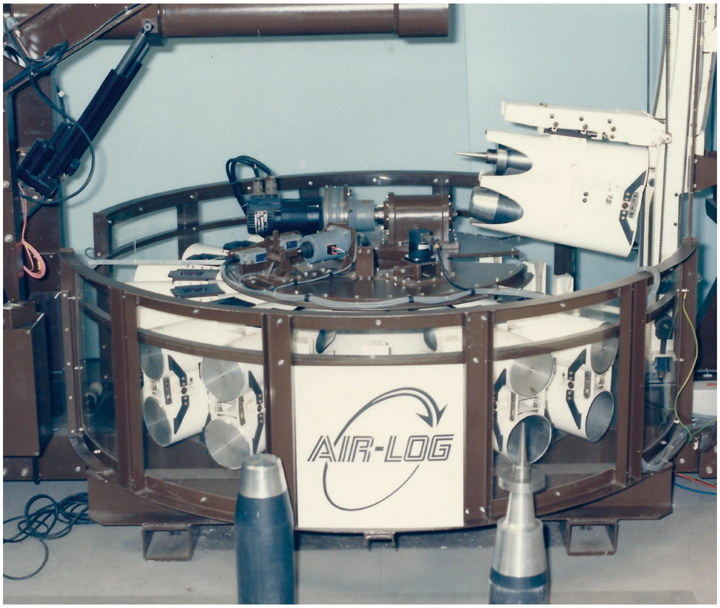
at different attitudes and it successfully operated at side tilts up to 20 degrees from 2 degrees depression to 10 degrees elevation. As part of acceptance testing 37,000 belt movements were undertaken and 830 simulated loading cycles with no significant wear to any components. A full demonstration of the device occurred on 23 June 1988.

Work to improve target acquisition and engagement covered trials of a panoramic thermal sight with an integrated CO2 laser and an Automatic Target Detection and Tracking (ATDT) system. The demonstration system was based on work already undertaken for MBT80 and ongoing research with the 'Weapons System Demonstrator'.

The Operational Demonstrator Programme investigated the endurance of three-man crews, command and control of a tank using indirect vision and the reliability of autoloaders. Following extensive trials and demonstration activities a major report was presented to the Future Tank Programme Steering Committee in March 1987.

The feasibility of three-man crews was assessed by 'Exercise Endura' which was carried out with BAOR in April 1986. A number of technology enhancements that would reduce crew workload were simulated for the trial, including secure radios, improved navigation, measures to reduce maintenance, improved food and food-heating facilities, a rapidly deployed camouflage system and an autoloader. The crew performance was assessed during exercises which extended over a 12-day period; the analysis of crew performance concluded that operations with a three-man crew were possible but could not be sustained for extended periods.

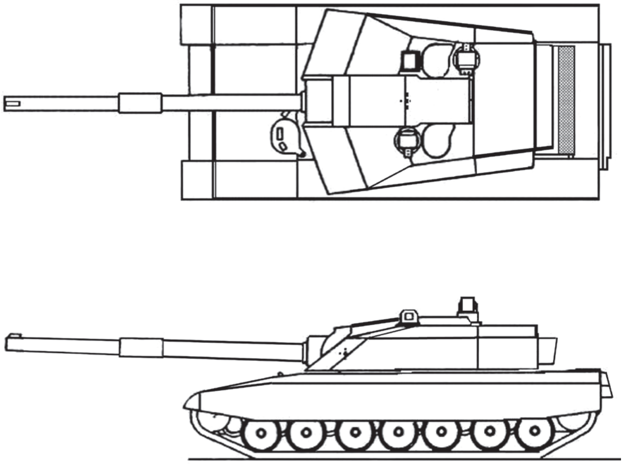
The work on indirect vison was mainly in support of external gun concepts and was carried out under the 'Vidi-Vici' (I saw, I conquered)



Demonstration carousel autoloader. (Crown Copyright MOD) project. It was a comprehensive investigation of operational aspects of remote vision. Three CVR(T) vehicles were fitted with mock-up turrets equipped with a range of stabilized and fixed cameras. They were used for a number of trials and demonstration activities investigating display configurations and performance aspects. The findings were first published in March 1987 in what was called the 'Commander's Choice' report; this concluded that command and control of an AFV was possible using remote vision systems but existing camera and display technology was assessed to be inadequate. The work set a baseline for future activities and performance targets for improved technologies. The overall user assessment confirmed the ongoing need for commanders to be able to operate 'head out' when required and highlighted that reliance on other crew members to observe over arcs he could not cover was not effective.

The autoloader study assessed the operation, rate of fire and survivability of autoloaders. It considered the two main types: carousel autoloaders, the preferred option as proposed by Chertsey for the 'Small Turret Concept', and bustle autoloaders which were being considered for upgrading Challenger. Full demonstrators of both types of autoloader were being built, but in advance of these being produced wooden mock-ups configured for 120mm rounds (with the stretch potential to take 140mm rounds) were built and assessed for aspects such as replenishment. Although the studies confirmed the viability of autoloaders the user community remained concerned about reliability issues.

Another major MBT concept study undertaken by Chertsey at this time was the Evolutionary National Tank concept which generated an initial report in December 1986 with studies continuing into 1987. As already discussed, it was used as a benchmark against which to compare the alternative offerings for Chieftain replacement. Although evolutionary, rather than revolutionary, in design, it was not constrained by any requirement to be based on Challenger 1 or its sub-systems. The resulting concept was for a vehicle with a three-man crew, a fully integrated gun and fire control system and a Battlefield Information System. It was planned to mount a 140mm main armament fed from a carousel autoloader; ammunition stowage being 40 rounds with 15 ready rounds in the carousel. The commander was to be provided with a panoramic day sight switchable between x3 and x12 magnification and the gunner with a stabilized day sight with integrated laser rangefinder. In addition, a panoramic thermal imager with integrated CO2 laser rangefinder was to be mounted behind the gunner's station; this sight



Evolutionary National Tank Concept. (Crown Copyright MOD)

could automatically align with either the commander's or gunner's sight to enable them to carry out surveillance and acquire targets in the thermal waveband. Overall, the concept was smaller and lighter than Challenger, yet provided better firepower and protection in addition to improved mobility. As well as the reduced crew number, size was also reduced through the use of a compact power pack. The proposed engine was based on a version of the CV8 engine that generated 1,000hp, hence giving a lower nominal engine power than Challenger. However, the vehicle was being designed to be 10 per cent lighter than Challenger and the engine was to be coupled to the very efficient TN55 gearbox, with its layshaft transmission giving more power to the sprockets. Therefore the effective power-to-weight ratio was expected to be at least as good as, or potentially better than, that of Challenger. Additional efficiency gains were achieved through the reduced cooling pack requirements. As well as a smaller engine and efficient compact gearbox the power pack had the engine mounted transversely to improve packaging efficiency and hence used a 'U' shape, rather than traditional 'T' shape, configuration. The TN55 gearbox provided eight forward and three reverse gears. The ENT was to have seven road wheels per side instead of the six on Challenger 1. However, the hydrogas units were repackaged so that overall the weight of the suspension was the same.

The basic design data for ENT was:

Weight: 62 tonnes
Length, hull: 7,200mm
Length, total: 10,800mm
Height, turret top: 2,480mm
Height, total: 2,670mm
Width: 3,480mm
Ground clearance: 450mm
Length of track on ground: 4,800mm
Nominal ground pressure: 97KPa
Fuel capacity: 1,100l

Main armament: 140mm
Stowed rounds: 40

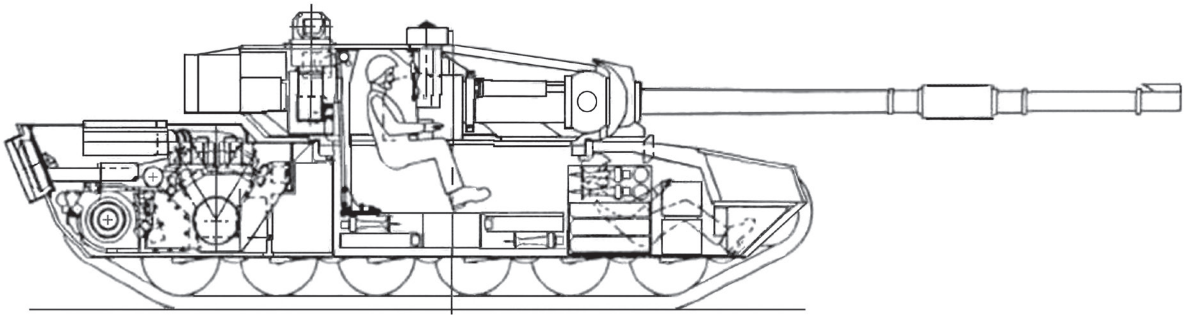
An outline development plan was drawn up which proposed feasibility studies to be completed by end 1989, 11 prototypes to be built by 1995 and an in-service date of 2001.

In July 1987 the Future Tank Committee commissioned a study into a potential Challenger replacement to be based on an evolution of the existing vehicle. The scope for any design modifications was flexible and included changes to both the hull and turret. A required focus of the study was to reduce the size and increase mobility in comparison with Challenger. The use of a three-man crew and an autoloader was seen as integral to achieving the required size reduction. Many of the ideas explored as part of the 'Small Turreted Tank' (Future Tank Concept A) and ENT studies were carried across but the assumed weapon was a 120mm gun rather than a 140mm. The resulting concept, called PIP87, was planned to use the CV12 engine from Challenger, rather than the CV8 in ENT, but linked to the same efficient TN55 gearbox to increase the effective power at the sprockets. The suspension used a repackaged version of hydrogas. The sighting system was improved in comparison to Challenger through the use of a panoramic thermal imager.

The basic characteristics of the PIP87 were:

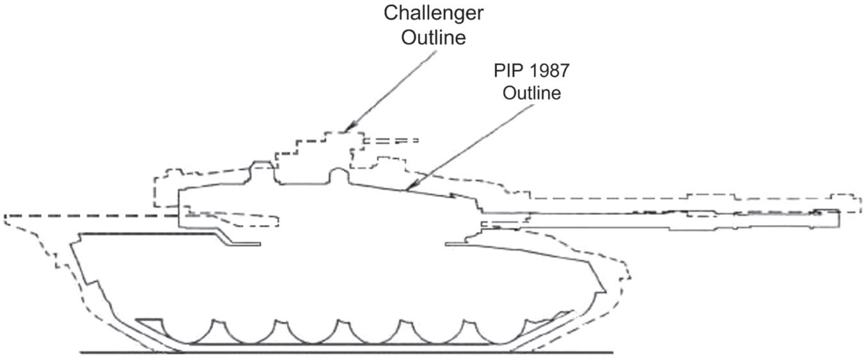
Weight: 54.5 tonnes
Width: 3,650mm
Length: 10,470mm, 6,970mm hull only
Ground clearance: 450mm
Main armament: 120mm
Stowed rounds: 40, of which 24 stored in the autoloader
Engine: RR CV12 at 932Kw (1,250hp)
Power-to-weight ratio: 16.9kw/tonne nominal, 13.7kw/tonne at the sprocket
Fuel capacity: 1,400l

A report describing the concept was issued in October 1989 and included an outline development plan for the delivery of the first prototype in late 1992 and an in-service date of 1998.



PIP 87, concept for an evolutionary development of Challenger that was significantly smaller. (Crown Copyright MOD)

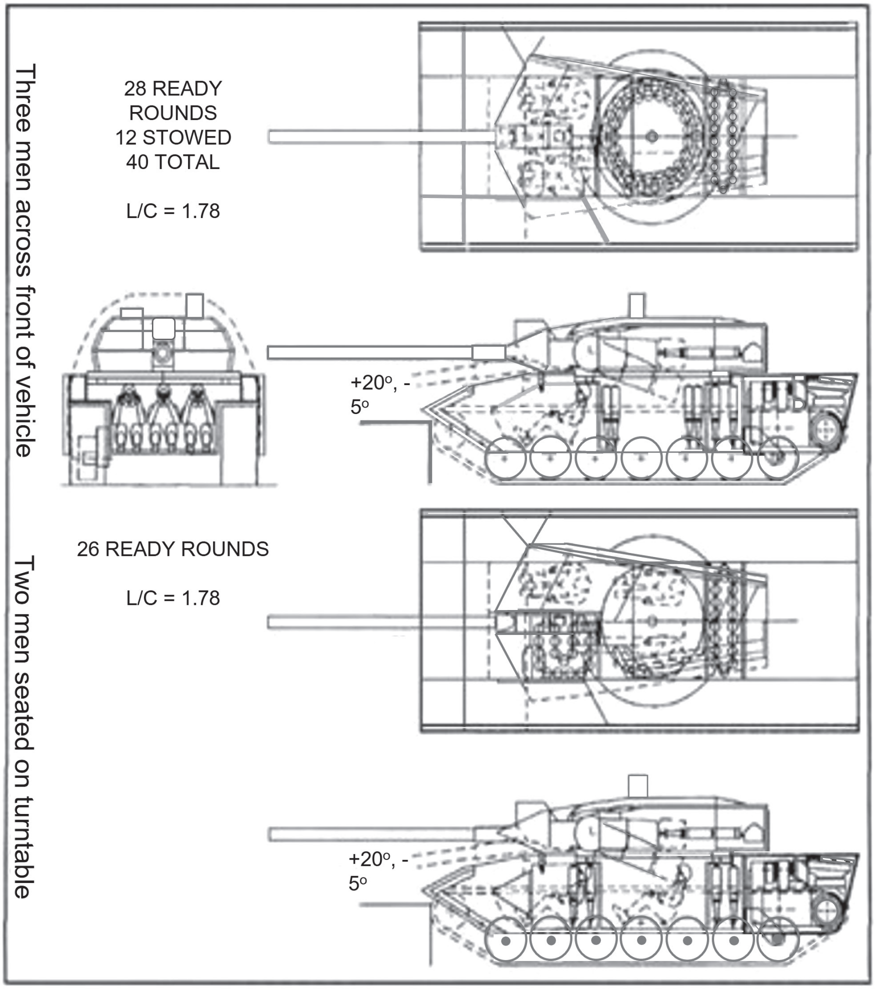
Work on developing a 140mm high-velocity gun, the Future Tank Main Armament (FTMA) programme, had been running as part of a joint activity between Germany, France, the UK and the USA. The use of a 140mm gun had been considered for some of the concepts developed at Chertsey, for example for the ENT concept. The goal of the FTMA project was to define interoperable ammunition, giving the nations the flexibility to develop their own guns should they desire. A Memorandum of Understanding (MOU) was signed by the four nations in 1990 and by April 1992 user representatives had agreed the 'Firepower Operational Objectives Statement'. Technical work started quickly and by 1991 the common gun chamber parameters had been standardized and RARDE had started developing a UK version of the US XM291 140mm gun. Government development activities were supported by industrial feasibility studies, contracts for which were placed in March 1993 with General Dynamics (USA), GIAT (France), Rheinmetall (Germany) and Royal Ordnance (UK). An FTMA Harmonization Study report was issued in November 1993 and that



Comparison of proposed PIP 87 silhouette and Challenger 1. (Crown Copyright MOD) contained a full system specification for the gun. By 1994 a number of successful trials had been carried out in the UK and confirmed the viability and safety of the proposed weapon design. The 140mm ammunition was longer than the equivalent 120mm round and was 90 per cent heavier. As the 140mm gun design started to mature some additional studies which focused specifically on the integration of the larger weapon were carried out. In 1991 Chertsey undertook an initial study to confirm the feasibility of mounting the 140mm weapon in Challenger 1. This was followed by the FTMA Integration Study which looked at mounting the 140mm weapon in Challenger 2 which reported in February 1994. The activities at Chertsey were supported by Vickers Defence Systems who undertook more detailed studies into the proposed solutions for mounting the weapon in Challenger 2. Three concepts were developed. Concept VDS1 was based on a direct replacement of the existing 120mm gun and retained the same four-man crew layout and aimed to minimize changes to the vehicles. The gun was mounted farther forward than the existing 120mm weapon to provide the required loading and recoil space behind the breach and so was out of balance. Two-piece ammunition was used with 12 ready rounds in the bustle plus 6 and 7 round racks in the hull. Concepts VDS2 and VDS3 both used one-piece ammunition in a bustle autoloader. Concept VDS2 retained the commander and gunner in their existing tandem location while VDS3 placed the two turret crew members either side of the gun breach. These concepts retained the main turret casting but required reworking of the rear of the turret to provide a much longer bustle to accommodate the autoloader. They also required significant changes to the hull to accommodate equipment displaced from the turret. Both VDS2 and 3 could accommodate 16 ready rounds in the autoloader and a further 14 in the hull.

The autoloader design was based on that developed by Fairey Hydraulics as part of the Future Tank Component Technology Demonstrator Programme. As stated for the VDS2 and VDS3 concepts only 16 rounds of 140mm ammunition could be accommodated compared with 20 rounds of the smaller diameter 120mm ammunition for which the autoloader was originally designed.

The VDS1 concept stowed 25 rounds of 140mm ammunition compared with 50 rounds of 120mm; but the total weight of stowed rounds was similar; hence the VDS1 140mm gun concept was estimated to weigh 500kg


Three men across front of vehicle
28 READY ROUNDS
12 STOWED
40 TOTAL
L/C = 1.78
+20°, -5°
Two men seated on turntable
26 READY ROUNDS
L/C = 1.78
+20°, -5°

FTMA 'Wide Tank' concept. (Crown Copyright MOD)

more than the 120mm Challenger 2 due to the heavier gun. The autoloader versions with 30 stowed rounds and the enlarged turret bustle was estimated to be 2 tonnes heavier than the standard Challenger 2.

Around this time the use of liquid propellant guns was revisited, in response to ongoing work at Fort Halstead, with a focus on how to store, pump and inject the fluid into the breach. However, the fundamental problems of the highly corrosive nature of the propellant had still not been addressed.

Chertsey undertook a wider range of studies for solutions based on Challenger 2 but with fewer constraints in terms of design changes. Three Challenger concepts were developed which all had bustle autoloaders:

- DRA1: New turret on the existing Challenger hull;
- DRA2: New turret on the existing hull but fitted with MTU883 1475hp power pack[12];
- DRA3: New turret on an up-armoured Challenger hull.

A related concept study undertaken at Chertsey was the 'Unconventional MBT Concepts Study' that reported in May 1994; as with many previous studies, the focus was on weight reduction. The study was carried out at the request of LSOR1, the Land Systems Operation Requirements Branch for close combat systems. Already aware of the likely weight increases for an MBT due to moving to FTMA 140mm they also recognized the potential requirement for increased armour protection leading to further weight growth, however, there was a desire not to exceed the 64.5 tonnes of Challenger 2. Studies into conventional solutions of a 140mm FTMA-based MBT with the required levels of protection had suggested the weight might be as high as 100 tonnes. Four concepts for potentially lower weight solutions were considered alongside the DRA3 concept, which, as a conventional evolution of Challenger, was used to assess their relative benefits. The unconventional concepts were:

- A 'wide tank' outside of the NATO rail gauge with carousel (rather than bustle) autoloader and three crew members;
- Front engine MBT;
- Unmanned turret concept;
- S-Tank type SPAT.

The increased width of the 'wide tank' concept, meant a carousel autoloader could be used which enabled a smaller and hence lighter turret to be used than was possible with a bustle autoloader solution. The commander and gunner were located either side of the breach. As well as the rounds stowed in the carousel there were additional rounds alongside the driver with a replenishment system to feed them into the carousel and further rounds were stowed at the rear of the crew compartment. The front engine tank used the turret with bustle

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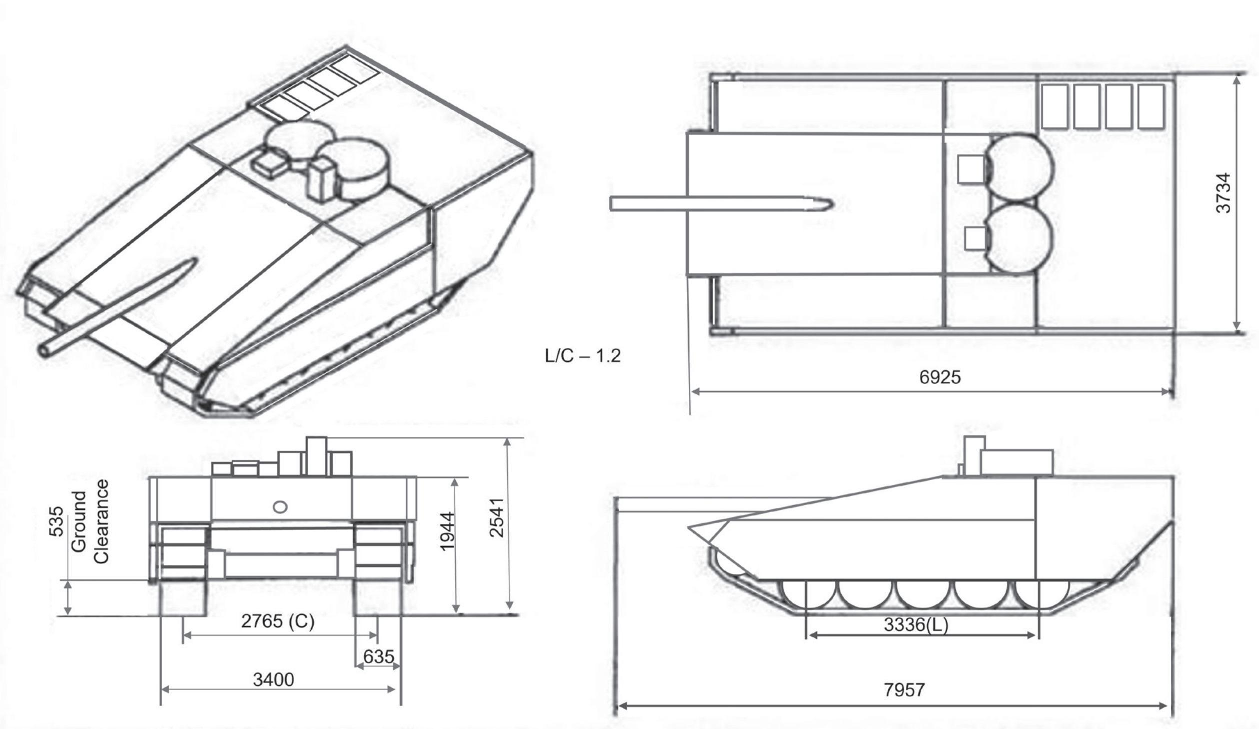
[12] This engine, as part of the so called 'Europack', had been fitted to a Challenger as part of the Chertsey research programme. This vehicle was marketed by Vickers as the Challenger 2E (Export) or Desert Challenger.



FTMA Fixed Gun (SPAT) concept. (Crown Copyright MOD)

autoloader for the conventional solutions but the layout provided space at the rear of the hull for additional rounds or fuel to be stowed and allowed easy access for replenishment. Two versions of a vehicle with an unmanned turret were considered, one providing only limited protection to the turret and the other with full MBT turret protection levels. In addition, variations with either the three-man crew across the front or with the driver at the front and the other crew sitting within the turret race ring were considered.

No significant weight reductions were achieved with the first two concepts, in fact the front engine concept was heavier due to the increased height of the hull front resulting in a heaver hull glacis plate. The front engine layout did give improved crew survivability and reduced the vulnerability of hull-stowed ammunition. Significant weight reductions were achieved with the concept with the limited protection on the unmanned turret. The fully protected unmanned turret gave only a limited reduction in weight; the unmanned turret being around three-quarters of the weight of the manned equivalent. Only the SPAT met the increased protection requirements within the weight limit.

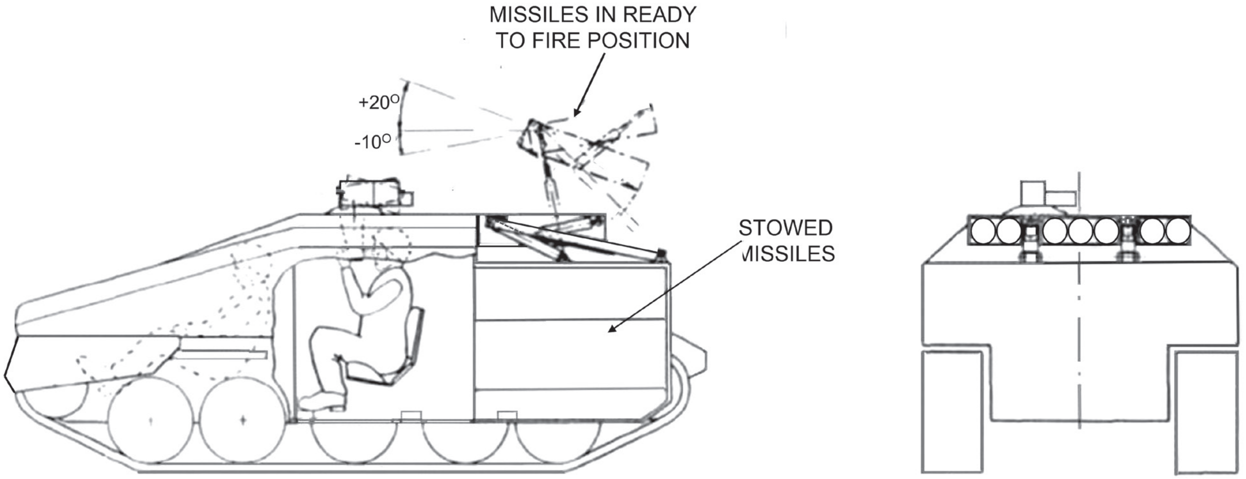
Another area where Chertsey undertook some tank concept work during the final years of the establishment was on vehicles armed with an electromagnetic (EM) gun. At the time there was an active EM gun research programme with the USA and a facility had been built at the Kirkcudbright range where testing of an experimental gun was undertaken. The status of technology at that time, especially in the areas of power generation and storage, meant that no viable concepts could be generated within an acceptable size and weight limit. The work did highlight the key areas where further development was required, setting priorities and design targets.

One final study into future MBTs was running at Chertsey before it closed in 2004; the Mobile Direct Fire Equipment Requirement, or MODIFIER, study. This was aimed at a replacement for Challenger 2 in 2023, but by naming it a 'Mobile Direct Fire system' it was intended to open up the scope for potential solutions beyond a like-for-like tank replacement. The project started in April 1997 and an Outline Staff Target was issued in August 1997. A key emphasis was on the use of new technologies, rather than just novel layouts, to produce a more agile, but survivable, vehicle; these technologies included electric drive, advanced sensors, active suspension, electric armour and active protection systems. The project did not run long enough for full concept designs to be generated. However, the high-level ideas being considered included:

- 50-tonne tank with an electromagnetic gun;
- 30-tonne missile launcher with 40 stowed missiles of various natures;
- Mix of two types of 40-tonne platforms, one with a 140mm gun and the other with missiles;
- 40-tonne unmanned tank;
- 25-tonne ATGW missile vehicle, based on the TRACER reconnaissance vehicle project running at the time;
- Wheeled missile-armed vehicle concepts;
- Light unmanned missile-armed concepts.

Later the scope of MODIFIER was expanded to encompass the replacement for both Challenger 2 and Warrior under the title of the 'Future Ground Manoeuvre Capability' with studies continuing within what was by this time called the Defence Science and Technology Laboratory (Dstl) at Fort Halstead.

Interest in uprating the British Army MBT fleet or procuring new platforms waned with the focus on operations in Afghanistan, but the need to revitalize the conventional warfare against well-equipped peer threats was recognized and at the time of writing a programme to upgrade Challenger 2 with an improved gun, armour, sighting system and other improvements is under way to deliver Challenger 3.


MISSILES IN READY
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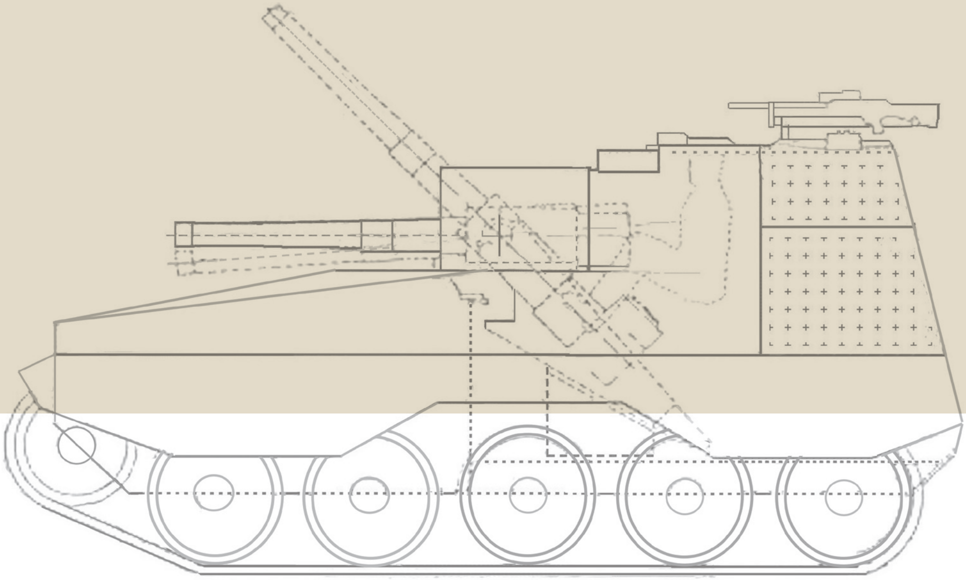
ABOVE
Concept for Striker modified to carry and fire MR Trigat. (Crown Copyright MOD)



PART 2

MEDIUM AND LIGHT TRACKED AFV DEVELOPMENT

ABOVE
FV304 line drawing of side view.
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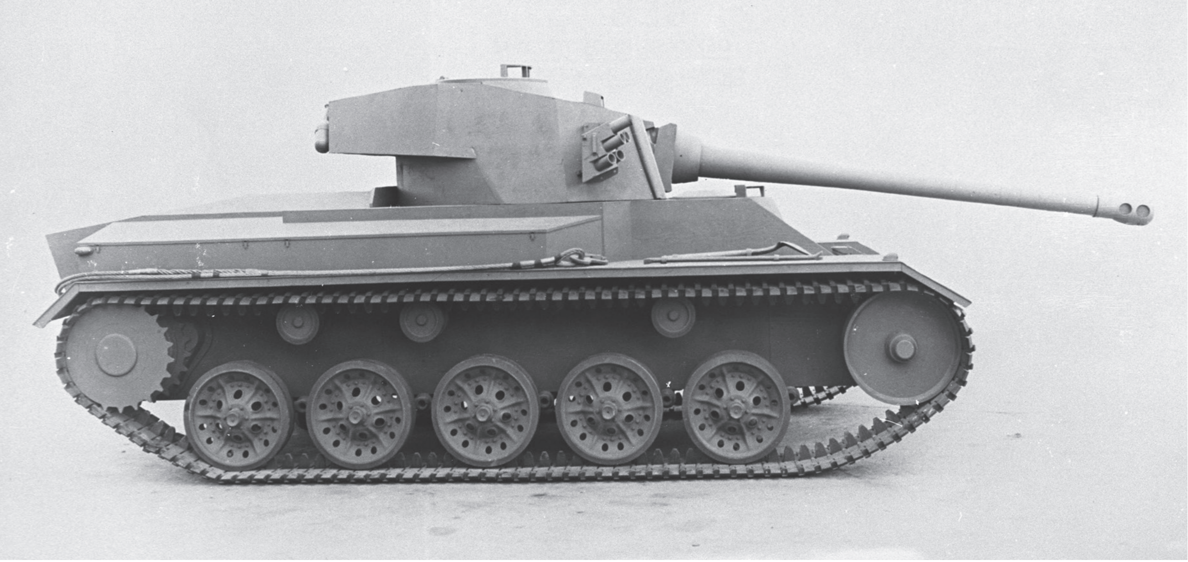
LIGHT TANKS AND COMBAT VEHICLE RECONNAISSANCE (TRACKED)



A46/FV301 mock-up. (The Tank Museum, Bovington)

One of the most noteworthy and successful vehicles designed at Chertsey was the Combat Vehicle Reconnaissance (Tracked) – CVR(T). It was actually a family of light tracked vehicles based on a common chassis and automotives which has served extensively with the British Army and was widely exported. It was not, however, the first light tracked armoured vehicle to be the subject of design activities there.

Work at the establishment on a new light tank – designated the A46 – had started during World War II. It was intended to replace the US Stuart and Chaffee tanks and following initial studies a contract was placed with Vickers to support the design work. The requirement specified a vehicle that was air transportable with a target weight of between 14 and 16 tons. It was to be powered by a 210hp GMC6-71 engine which had been fitted to some Valentine tanks. The possibility of transporting major sub-systems such as the turret, or gun and tracks, in a separate aircraft to the hull, was considered to maintain aircraft range;

this was long before a similar 'Fly Light – Fight Heavy' concept for vehicles was considered in the 1990s. Progress on the design was slow but a wooden mock-up was built and an assessment of this resulted in a number of recommended design changes being identified. These including fitting a different engine, a 350hp engine based on the Meteor and called the Meteorite. Along with the new engine a revised transmission layout was designed. Following the end of hostilities an interim policy for 'light' tanks was drawn up; this was to continue to field the Cromwell and Stuart IV in the short term in the light tank role, with the goal of developing a new vehicle, called the FV301, to replace them as soon as possible. Therefore in 1946 there was renewed interest in the A46 project which was reinvigorated as the basis for FV301. As well as a light tank the requirement specified a family of other vehicles. The light tank was designed to meet a requirement for a tracked reconnaissance vehicle to supplement wheeled armoured cars. The design was based around a 400hp version of the Meteorite engine linked to a Merritt-Wilson triple differential gearbox (called the TN10). With 50mm frontal armour the initial target weight was around 21–24 tons. The suspension was torsion bar and the main weapon a '77mm'[13] gun. The width was limited to 2.9m for rail transportation. The outline design was complete by August 1947 at which time a contract was placed for full design and the manufacture of a pilot model made of non-armour steel. Flotation equipment and an appliqué dozer blade were also designed.

The intended family of vehicles was:

FV301: Light Tank
FV302: Command Post
FV303: 20-pdr SP anti-tank gun
FV304: 25-pdr SP field gun
FV305: 5.5in. SP field gun
FV306: Light ARV
FV307: Radar vehicle
FV308: Field artillery tractor
FV309: Ammunition vehicle
FV310: Light Armoured Personnel Carrier (APC)
FV311: Armoured load carrier

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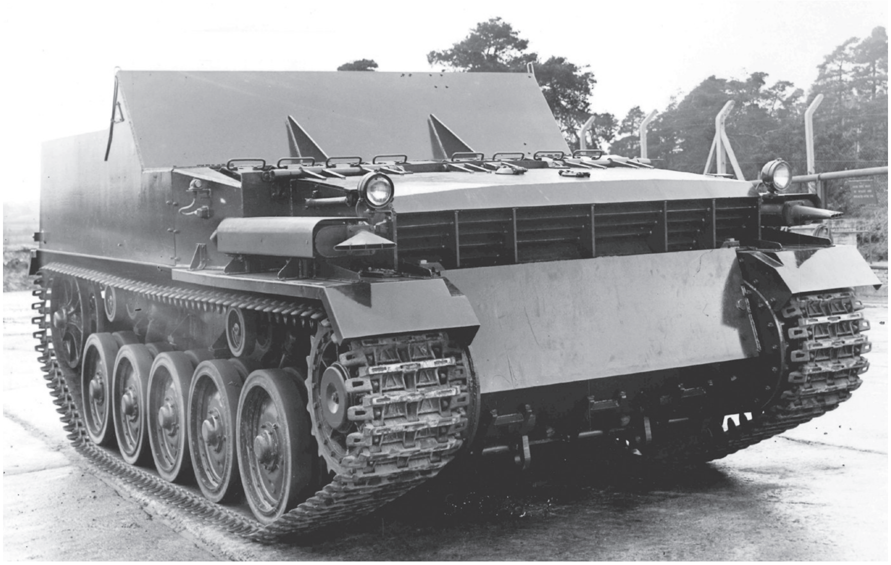
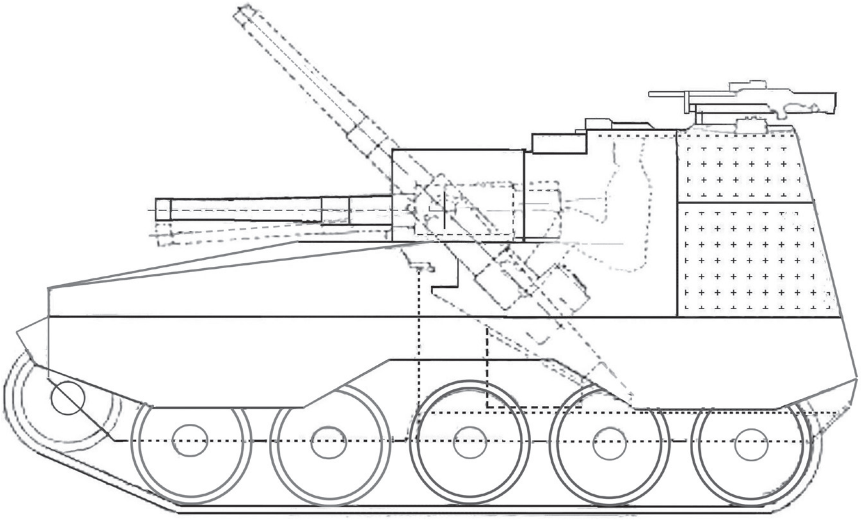
[13] This was based on the 76.2mm gun fitted to the Comet tank which was referred to as a 77mm gun.



FV300 hull rear view. (The Tank Museum, Bovington)

Initially the development of the variants followed after that of FV301 in priority order as defined by the Army; hence by the time the detailed design of FV301 had started, the initial design work on FV303 and FV304 was under way, FV306 was at the concept phase and the specification for FV310 was being circulated for approval. In addition to the above variants a design study was undertaken for a flamethrower version, but this was not taken forward due to cost considerations. By 1948 the priority had shifted to self-propelled gun variants required to replace World War II SP guns, hence FV305 was then nominated as the most urgently needed vehicle although work on the FV303 and FV304 was more advanced at that time. Work to support the FV304 had included the build of a mock-up of the crew compartment which had been trialled in July 1948 to assess the ability of the crew to load the weapon within the cramped confines due to a 60-round stowage requirement. In 1949 the decision was made to maintain focus on the front engine variants, and in addition to the ongoing focus on the SP variants there was a growing priority being given to the FV310 light APC. By this time development of FV301 had effectively stopped but a prototype had been built. This was a 21-ton vehicle with the hull frontal armour limited to 35mm to save weight, but sloped at 55 degrees. It was armed with the '77mm' gun which was mounted well forward to minimize the space intrusion into the turret. This resulted in an out-of-balance configuration that required the use of an equilibriator and a new concentric recoil system. 60 rounds of ammunition were stowed. The torsion bar suspension supported five road wheels on each side. The engine power was up to 500hp which was delivered to the sprockets through a Merritt epicyclic gearbox giving a maximum speed of 34kph. Overall dimensions were: length 7.34m overall, 5.36m hull, width 2.97m and height 2.49m. The FV310 was to be heavier than the FV301 but have a slightly more powerful version of the Meteorite engine. It was being designed to carry 12 men plus a crew of two. The armour protection levels were: 25mm front, 20mm side and 17mm top. Dimensions were: 5.5m long, 2.9m wide and 2m high. Tracks were just over 0.5m wide. A cupola-mounted machine was to be fitted for self-defence purposes. The APC was also to be used as the basis for a command variant.

In addition to FV301, prototypes are known to have been constructed for the FV302, FV303 and FV304. All work was subsequently focused on the SP variants and continued until 1953 when activity was stopped following the initiation of the FV3800 project which covered a series of SP guns based on Centurion power train and running gear. One of the reasons why work on FV301 was stopped was concerns about its cost effectiveness with the small number expected to be required by the British Army, but there were also concerns about the utility of light tanks. An FV300 series hull was, however, later used as test bed for the TN15 gearbox and some aspects of the design, for example the torsion bar suspension, were carried over to later vehicle designs and eventually into the CVR(T) family. One new feature of the FV300 series, which became standard in future vehicles,



FV304 line drawing of side view. (Crown Copyright MOD) was the combination of the engine and gearbox into a single unit, or power pack, for quicker fitting and removal.

In 1960 the Armoured Vehicle Reconnaissance (AVR) programme was started to develop a replacement for the Saladin wheeled armoured car with its requirements defined in GSR 1010. The Fighting Vehicles Research and Development Establishment drew up a number of wheeled and tracked concepts that were presented to the Army General Staff in December 1961. One novel tracked concept could mount either a 75mm or 105mm gun in a limited traverse turret with Swingfire Anti-Tank missiles in the rear. Another unusual feature of the concept was that the driver was positioned in the turret. Some automotive components were planned to be common with the FV432. The wheeled concepts are discussed in a later section.

In April 1962 a 'War Office Policy' (WOP) document on reconnaissance was issued. This defined that there would be three elements contributing to the British Army reconnaissance capability:

- Armoured Vehicle Reconnaissance;
- Scout vehicles;
- Air platforms.

The aerial reconnaissance was to be provided by a mix of helicopters and light aircraft. Two versions of the Scout Vehicle were required; Scout Vehicle (Recce) and Scout Vehicle (Liaison). These were to be based on the existing Ferret Mark 1 and Mark 2 vehicles but with overhead cover fitted to the Mark 1 and Vigilant Anti-Tank Guided Weapons fitted to some Mark 2s. Both vehicles were required to have flotation aids.

The AVR requirement as defined in the WOP was to be met by a new vehicle to be developed jointly with Canada and the USA. It was to be fitted with long-range day and night sensors and be air transportable in a Beverley aircraft. The WOP left the option open for wheeled or tracked solutions with the tracked version to be supported by FV432 and the wheeled version by Saracen. A further WOP, dated May 1962, defined a requirement for an air-portable AFV, with an in-service date of between 1971 and 1975, to be used to support light forces until the arrival of heavy armour. This was also required to be air transportable in a Beverley and had requirements for a high level of mobility and the ability to defeat heavy tanks by day and by night.

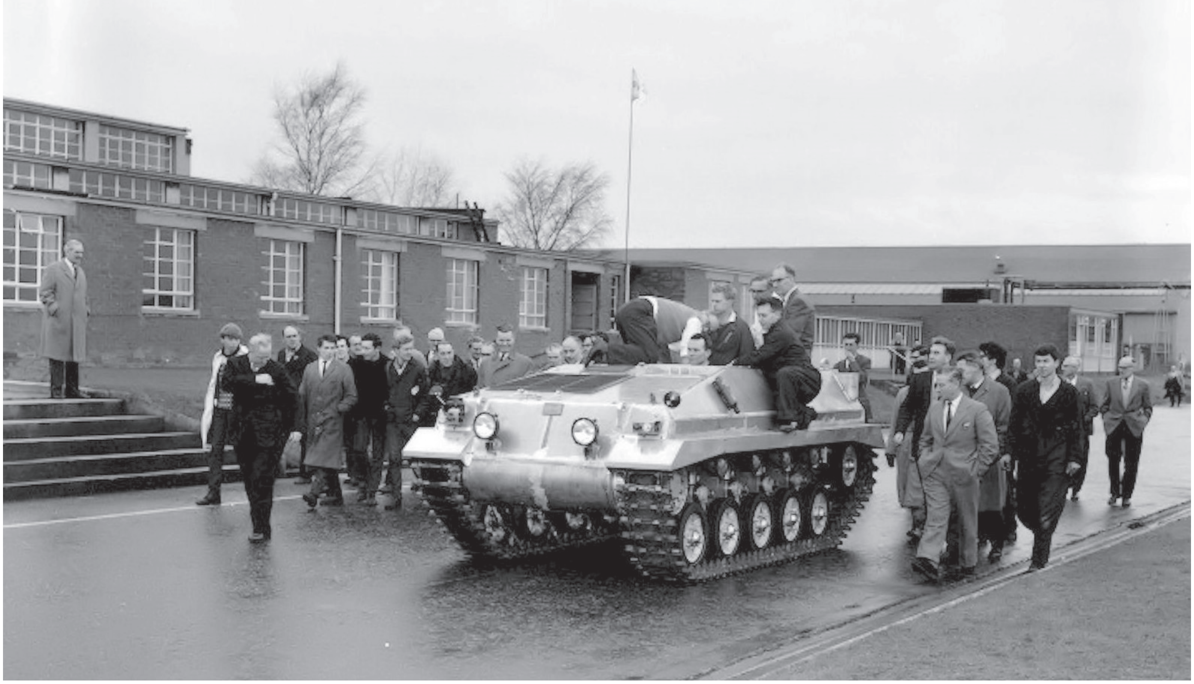
The statement in the WOP about a joint development programme was made in light of ongoing discussion with Canada and the USA concerning a possible joint light-armoured vehicle project, with Australia also expressing interest. This joint development programme did not materialize and the UK stopped work on AVR as, with the weight projected to be over 13 tonnes, it was considered too heavy, work was therefore refocused on a national programme looking at lighter solutions. The US also pursued a national programme to address their requirement for an Armoured Reconnaissance Vehicle/Air Assault Vehicle; this resulted in the M551 Sheridan.

Meanwhile an additional requirement, GSR 1006, had been drawn up for air-portable vehicles and studies were carried out into what was called the 'Lightweight High Mobility Tracked Vehicle' (LHMTV) project. Two LHMTV reports were issued in 1961, the first a concept report and then a report entitled, 'Preliminary Assessment of GSR 1006 Air Portable AFVs'. A report with refined concept studies for LHMTV was issued in 1964. The LHMTV concepts informed the formulation tracked solutions for AVR.

As well as fluidity in the vehicle requirements there were also shifts in weight targets based on which aircraft the vehicle had to be transported in or air-dropped from. The original AVR requirement was for transport in a Beverley aircraft which could carry a vehicle of around 5.7 tonnes. The LHMTV had a requirement based on the HSA 681 aircraft, which had a total payload of around 16 tonnes, in which two vehicles were to be transported or a single vehicle air-dropped. The HSA 681 project was subsequently cancelled.

It was recognized that the British Army requirements could not be met by a single vehicle within the constrained weight limits, hence the concept of a family of vehicles was developed and this formed the basis of the CVR(T) programme. Work on the CVR(T) programme started with concept studies which ran from 1963 to 1965 with refined requirements being defined in GSR 3301 which was issued in August 1964. At this stage the decision was made to focus on a tracked solution; this decision was partly based on ongoing concerns about the viability of the skid steer proposed for the wheeled options which was necessary if they were to meet the size and weight requirements. The original AVR project was intended as a replacement for Saladin, but the requirement was now extended to cover Saracen as well. Further, the design brief required it to have the same performance on roads as the wheeled vehicles it replaced as well as significantly greater off-road mobility and access to marginal terrain. In order to understand the design drivers for the mobility of low ground pressure tracked vehicles, trials were carried out on a Tetrarch light tank with the turret removed. The air-transportability requirement, which at that time was still based on the HSA 681 requirements, put severe constraints on weight and so it was decided that the vehicle would need to be built of aluminium armour. Aluminium had already been used on armoured vehicles, most notably the US M113 Armoured Personnel Carrier, but the CVR(T) was the first turreted AFV to be made completely of armour grade aluminium.

Some of the technologies and design aspects for CVR(T) were demonstrated on a test rig called the TV15000. This vehicle was driven out of the workshops on Christmas Eve 1965; the workshops having been provided with the first drawings in June that year and given the challenge to have it finished within six months. This vehicle had an aluminium hull of a configuration similar to that adopted for CVR(T), but slightly larger. The engine fitted for the roll-out was a Rolls-Royce Vandan-Plas engine (a variant of the B60 engine). It had separate gearbox and steer units and so the resulting power pack would have been too


TV15000 roll-out on Christmas Eve 1965 with some of the staff involved with the design and build. (Crown Copyright MOD)

large for CVR(T). The original engine was not running well during the roll-out and in the photographs of the event one member of the workshop team can be seen on the hull operating one of the carburettor dash pots by hand. Different engines were fitted during the life of TV15000 including the Jaguar engine which was finally selected for CVR(T); this was fitted in 1966. The vehicle also used an early version of hydrogas suspension, but this was not taken forward for CVR(T) as it was seen as being too high risk compared with the torsion bars already demonstrated on FV300. Later the vehicle was fitted with a lightweight aluminium track and in this configuration achieved a top speed of 77kph. Based on the concepts developed by FVRDE and the successful demonstration of key technologies and features, approval for full development of the CVR(T) family of vehicles was given in August 1965. One of the first steps once development had been approved was for FVRDE to build two test rigs. The first was a static rig which represented the front of the hull and was used to test the engine installation and cooling performance. The second was the Mobile Test Rig (MTR).

TV15000 continued to be used as a mobility research vehicle and for a while it was run without its turret in support of studies to assess the performance of vehicles with different power-to-weight ratios and the impact on driver performance.

To meet the demanding weight requirements CVR(T) was fabricated using 7039 aluminium zinc magnesium alloy. This was lighter than the 5083 aluminium manganese magnesium alloy used on M113, but much more difficult to weld. Therefore, in addition to developing the amour specification, Chertsey undertook a significant amount of work to develop techniques for welding, forging, fixing stud inserts and corrosion resistance. Work was also undertaken to determine the optimum slope of the armour to defeat kinetic energy threats. As well as using aluminium for the hull and turret structure CVR(T) also exploited research into aluminium components, such as road wheels and suspension arms, to further reduce weight. As well as the weight limit another design challenge was the requirement to limit the width to 2.1m, specified for mobility in plantations and along narrow tracks. This width limitation was a particular issue for the front of the vehicle and the packaging of the power pack alongside the driver. The limited width of the engine compartment was one of the drivers for selecting the Jaguar XK six-cylinder engine. This was a militarized version of the

FV101 prototype during trials. (Crown Copyright MOD)

car engine running at 195bhp, rather than 265bhp, but able to run on low-octane military grades of petrol. The design of the engine compartment also allowed for the potential to fit a General Motors 4-53T diesel engine; however, this was much heavier than the Jaguar engine. A further challenge was the transmission. Previous light vehicles, such as the Oxford Carrier, had used a gearbox linked to a Cletrac steer unit, however, the confined space dictated that a combined transmission unit was required, in addition there were concerns that the relatively basic Cletrac steer unit would not cope with steering at the higher speeds envisaged for CVR(T). A further complication was that when development of the gearbox started, a final decision on the engine to be used had not been made and at that time Perkins T6-354 and GM 4-53T diesel engines were being considered as well as the Jaguar 4.2-litre petrol engine; hence the gearbox had to be designed to work with any of these engine options. A hydrostatic gearbox was considered but was assessed to lack maturity at that time. Therefore, Chertsey developed a concept for a combined transmission and steer unit using the Merritt system. The design was passed to Self-Changing

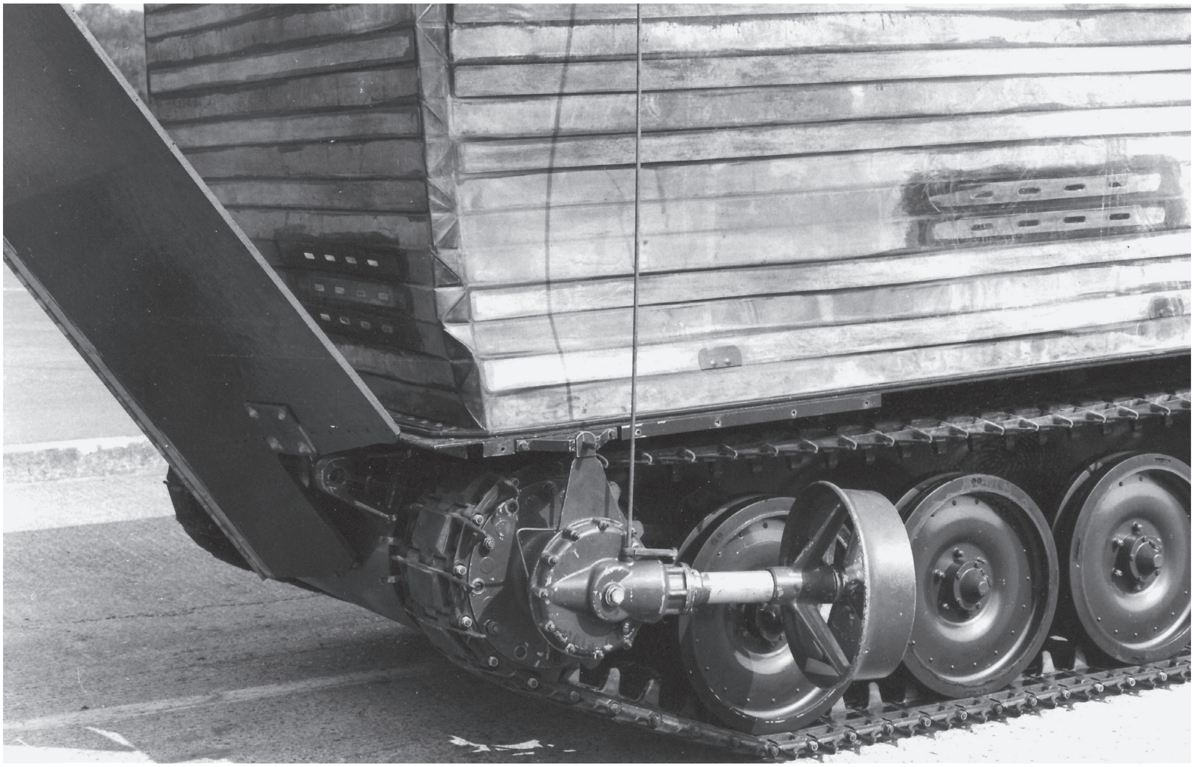
Gears and in February 1966 a contract was placed for the production of more detailed designs along with cost and performance estimates. The value of this contract was £1,200. Following further design studies a contract was placed in October 1967 for the build of 30 units. The first unit began testing at Self-Changing Gears early in March 1968 and the second unit was delivered to Chertsey in July 1968 for testing in the mobile test rig. In December 1968 prototype transmission No.5 was delivered to Alvis for fitting to the first prototype vehicle. There were some issues that had to be addressed during the development, in particular with the gear selector controller and some of the friction plates. Also, some design changes were made to improve performance when swimming. However, overall the development was considered a great success.

In 1967 a development contract was placed with Alvis covering detailed design and prototype build. Alvis delivered the first prototype on 23 January 1969 and a total of 30 prototypes were eventually delivered; prototypes 1 to 17 being Scorpions with the rest being examples of the other variants. There followed an extensive period of development and user trials. The assessment of CVR(T) included extensive cold weather and mobility trials of a Scorpion in Canada in an exercise called 'Prairie Snow' carried out in 1971.

The vehicle was accepted for service in 1970 and a production contract placed with Alvis. Production examples of FV101 Scorpion, which was the first variant to be fielded, were issued to the Blues and Royals in 1972, with production for the British Army completed in 1974.

As discussed, an important feature of the CVR(T) was the family of different variants to meet the British Army requirements, all with a common power pack and running gear. The initial list of variants was:

FV101: Scorpion; Reconnaissance vehicle with the L23A1 76mm gun
FV102: Striker; Anti-Tank Guided Weapon Launcher firing the Swingfire missile
FV103: Spartan; Armoured Personnel Carrier
FV104: Samaritan; Ambulance
FV105: Sultan; Headquarters
FV106: Samson; Recovery
FV107: Scimitar; Reconnaissance vehicle with 30mm gun



CVR(T) with auxiliary propellers. (Crown Copyright MOD)

The development and fielding of these followed in priority order as defined by the Army and by November 1975 the design and manufacture status of the fleet was:

FV101: Production complete
FV102: First prototype manufactured
FV103: Delivery and acceptance of first two production vehicles
FV104: No prototypes – planned fielding 1978
FV105: Acceptance just achieved, first production vehicle due May 1976
FV106: Prototypes completed, user trials expected to be completed November 1976
FV107: Production under way, due to be complete in 1976

All the CVR(T) variants were manufactured in armour grade aluminium and had a similar configuration based around a forward engine compartment with the driver to the left of the engine compartment bulkhead and compartment across the full width of the vehicle at the front housing the gear box/steer unit. The drive sprocket was at the front of the vehicle and the suspension system consisted of five road wheels per side mounted on torsion bars. The variants had one of three basic configurations, turreted (FV101 and FV107), rear armoured compartment (FV102, FV103 and FV106) or rear armoured compartment with a higher roof line (FV104 and FV105). As-built, all variants were fitted with a collapsible screen for swimming and could be equipped with auxiliary propellers for higher water speeds.

The light weight of the vehicle and the use of tracks gave the vehicle a very low ground pressure which enables it to operate over a wide range of terrains including soft soils and mud where many other vehicles would sink in. Another aim of the design was to reduce noise and special attention was paid to the engine fan noise and the sprocket design.

FV101 SCORPION AND FV107 SCIMITAR

The Scorpion and Scimitar variants both have a three-man crew consisting of a driver in the hull and a gunner and commander in the turret. The two-man turret is mounted towards the rear on the hull, the top of which is lower than the other variants, and the NBC pack is located across the rear of the hull as there is no requirement for a rear hatch. The commander is on the left-hand side of the turret and the gunner on the right. The gun is aimed manually with the gunner having a right-hand-operated traverse handle with coarse and fine traverse gearbox modes and a left-hand-operated elevation handle which also has the firing switch. A firing selector box to the right of the gunner has a three-position switch for off, main armament or coax selection. The vehicle was originally equipped with an advanced infrared sight and an infrared driving sight.

The Scorpion is armed with the L23A1 76mm gun which was a lighter development of the L5A1 mounted on the Saladin armoured car. The 30mm armament on the Scimitar was developed especially for fitting to that vehicle, Fox and FV432. Initial research into 30mm cannon systems had started in 1960 and analytical studies carried out in 1963 confirmed that a weapon of that size would be needed to defeat threat APCs. A separate requirement, GSR 1012, defined the required characteristics of the weapon and in 1964 a final report was issued called ‘GSR 1012 Assessment of Possible Solutions’ which recommended the

30mm weapon as the most suitable for defeating the assumed threat armour thickness of 25mm; by then work on an experimental 30mm cannon was well under way. Initial concepts for what became Fox and Scimitar had been based on the use of a 20mm Hispano-Suiza cannon but by 1966 what became the 30mm RARDEN[14] was being used in the designs being generated by FVRDE. By this time a 30mm Hispano-Suiza cannon was available but compact design of the RARDEN gave significant packaging advantages:

Inboard length: RARDEN: 43cm	Hispano-Suiza: 101cm
Weight: RARDEN: 108kg	Hispano-Suiza: 136kg
Trunion pull: RARDEN: 1,360kgf	Hispano-Suiza: 1,510kgf

To reduce development risk and time the RARDEN was designed to use Anglicized versions of the Hispano-Suiza ammunition, but an APDS round was also developed. The resulting Scimitar vehicle with the 30mm RARDEN had a Scorpion turret but the mantlet and gun mounting of Fox. The basic weapon aiming was the same manual system as for Scorpion with a two-speed traverse gearbox for either rapid turning or fine gun laying.

In 1995, 136 Scorpion vehicles were modified by replacing the 76mm gun turret with surplus Fox turrets, which had the same 30mm gun as Scimitar; this version was called Sabre.

All the other main variants of CVR(T) had a higher hull roof line than Scorpion providing an armoured compartment across the rear half of the vehicle and with an access door across the back. The NBC pack was relocated to the left side of the hull for these vehicles.

FV102 STRIKER

Striker was an ATGW system equipped with the Swingfire missile. Five ready-to-fire missiles could be loaded into an armoured launcher module hinged at the rear of the hull, with a further five spare missiles carried inside the vehicle. In order to launch missiles, the launcher module was raised from the horizontal to 35 degrees; but in the travelling position the launcher was

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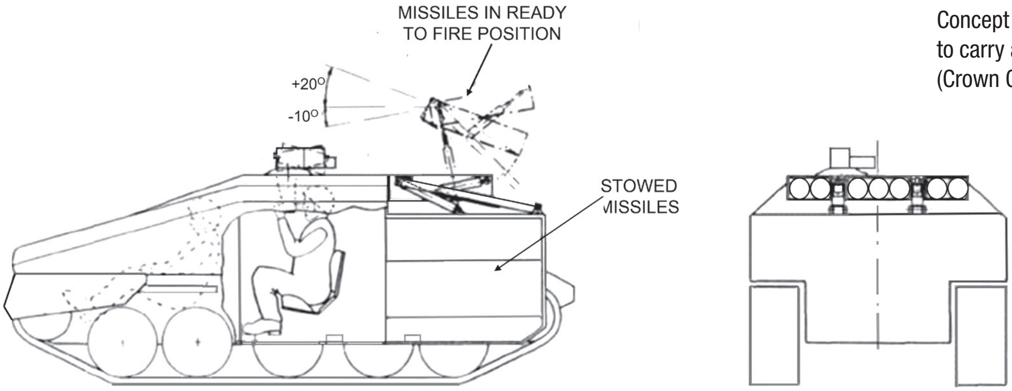
[14] The name RARDEN was originally derived from the two establishments that developed it, Royal Armaments Research and Development Establishment and Enfield but it was used as a name rather than an abbreviation.



Concept for Striker modified to carry and fire MR Trigat. (Crown Copyright MOD)

horizontal so that from a distance the vehicle had the same silhouette as Spartan. GSR 3301 for Striker was approved in July 1965 and following initial studies a project study contract was placed with the BAC, which was the design parent for Swingfire. Full development of Striker started in May 1970 and the first prototype was ready for trials in May 1972, with user trials starting in May 1973. Striker was cleared for in-service use in June 1974. As well as being able to launch and guide the missiles from the vehicle a remote sight and control unit could be used from up to 100m from the vehicle. The system was later updated under the 'Swingfire With Improved Guidance' (SWIG) programme which provided a Semi-Automatic Command Line Of Sight (SACLOS) guidance system as well as a thermal imaging sight. In addition to the new sighting and guidance systems a range of other modifications were required including changes to the internal stowage to make room for a compressor for cooling of the thermal imager. Sometimes referred to as Striker 2 it completed user trials in 1995 and was intended to provide an interim improved capability until the planned TRACER Guided Weapon overwatch vehicle was developed. However, it was never fielded and Striker was taken out of British Army service in 2005.

Earlier, in March 1984, a study was undertaken into converting Striker to carry the Medium Range Trigat ATGM that was under development at that time, but work stopped when the missile programme was cancelled. The Striker-based Trigat concept had seven ready-to-fire missiles in an elevating pod, plus other missiles stored under armour ready for reloading. A simple turret with two missiles, similar to the Milan Compact turret, was also considered. In 1990 a study was carried into the fitting of Hellfire missiles on both Striker and Spartan which generated schemes for eight externally mounted missiles.

FV107 Scimitar with a 30mm RARDEN cannon. (Author's Collection)

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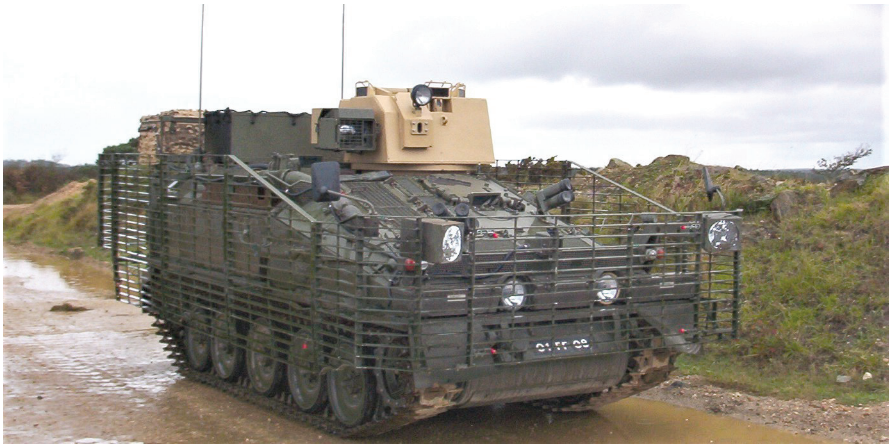
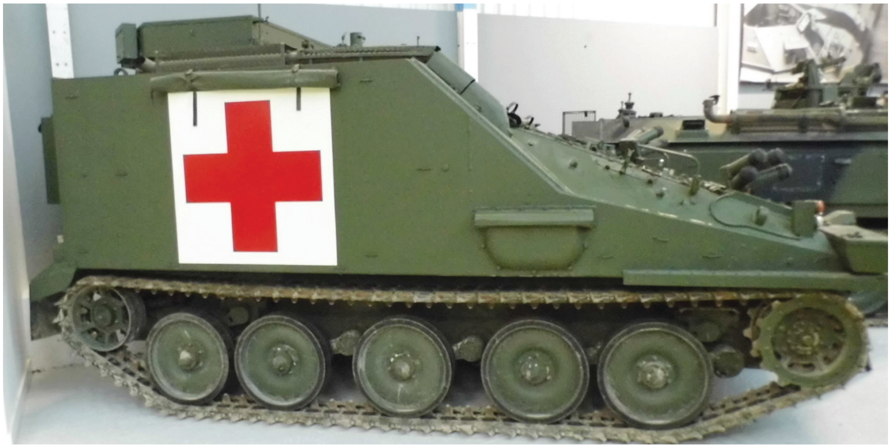
FV103 SPARTAN

Spartan was developed as an Armoured Personnel Carrier with a crew of seven, five of which could be a squad of four fully equipped soldiers with a commander. The basic version was fitted with a small cupola armed with an L37A2 7.62 General Purpose Machine Gun with an aligned site and spotlight operated by the commander. Aiming was manual with a right-hand traverse handle and a left-hand elevation handle which also had the firing switch. Additional firepower came from the weapons carried by the dismounts which could include rifles, machine guns and light anti-tank weapons. In addition to use as a troop carrier Spartan was intended for use as a resupply vehicle for Striker and to carry a range of equipment including mines and explosives or a surveillance radar.

Later some Spartans were fitted with the Euromissile Milan Compact Turret which carried two missile launch rails and was procured against GSR 3913. The compact turret had originally been demonstrated to the British Army in Germany in May 1980 fitted to a Fuchs APC. In August 1983 GSR 3913 was endorsed and trials of the 'Milan Compact Turret Spartan' (MCT/S) were carried out by the Infantry Trials and Development Unit (ITDU) in November 1984. A full production specification for procurement (DGFVE Spec 423) was issued in October 1985. The conversion kit consisted of a six-sided armoured turret adaptor, which was a box fitted over the main hull compartment, onto which the turret was mounted. Internal stowage for 11 missiles was provided. The weight of the vehicle increased to 8.5 tonnes and the height without the site was 2.8m.



Spartan with 'Theatre Entry Standard' upgrades. (Author's Collection)



FV104 Samaritan armoured ambulance. (Author's Collection)

FV104 SAMARITAN

Development of the Samaritan Ambulance variant started in March 1970 and the prototype (P22) was delivered in September 1972. Initial user trials were undertaken in November 1972 and, following technical trials, full user trials were carried out between March and June 1976 with an acceptance meeting held in July 1976. A key focus of trials was to confirm that the increase in weight over that of Scorpion did not result in a significant degradation in reliability. The vehicle has a similar overall layout to Spartan but with a higher roof line giving an extra 300mm of headroom inside. Unlike Spartan a crew cooling system is provided. There is room down each side of the crew compartment for two stretcher cases. The vehicle commander is located at the front of the compartment under a cupola and the medical orderly at the rear of the vehicle on a tip-down seat mounted on the rear door.

FV105 SULTAN

Like Samaritan the Sultan is a 'high body' variant of the CVR(T) family and was the first purpose-built tracked command vehicle to be produced in the UK since World War II. It was intended to replace the Saracen command vehicle in Armoured Reconnaissance Squadrons and Regimental Headquarters and the FV432 Command vehicle in Armoured Battle Groups.

FV105 Sultan and FV439 forming part of a field HQ. (Author's Collection)

The prototype (P21) was initially evaluated by the Army at the Armoured Trails and Development Unit in April/May 1972. After testing by MVEE and fitting of a full Clansman radio harness the prototype returned to ATDU for acceptance testing in April 1975. It was recommended for acceptance in October 1975 subject to minor changes. The vehicle was equipped with extra radios, a map board, additional batteries and a tent to form a penthouse extension at the rear of the vehicle.

FV106 SAMSON

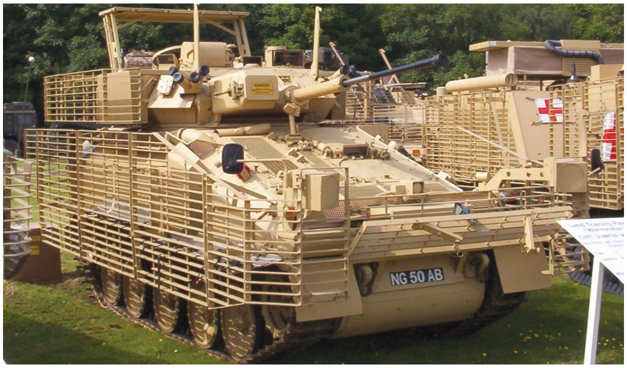
The Samson recovery variant uses a very similar hull to the Spartan but has a winch mounted in the main compartment with the recovery rope deployed through the rear door. An earth anchor is mounted at the rear of the vehicle. The winch has a maximum pull of 20 tons. It is provided with 225m of wire rope and the winch can operate at pay-on speeds up to 120m per minute.

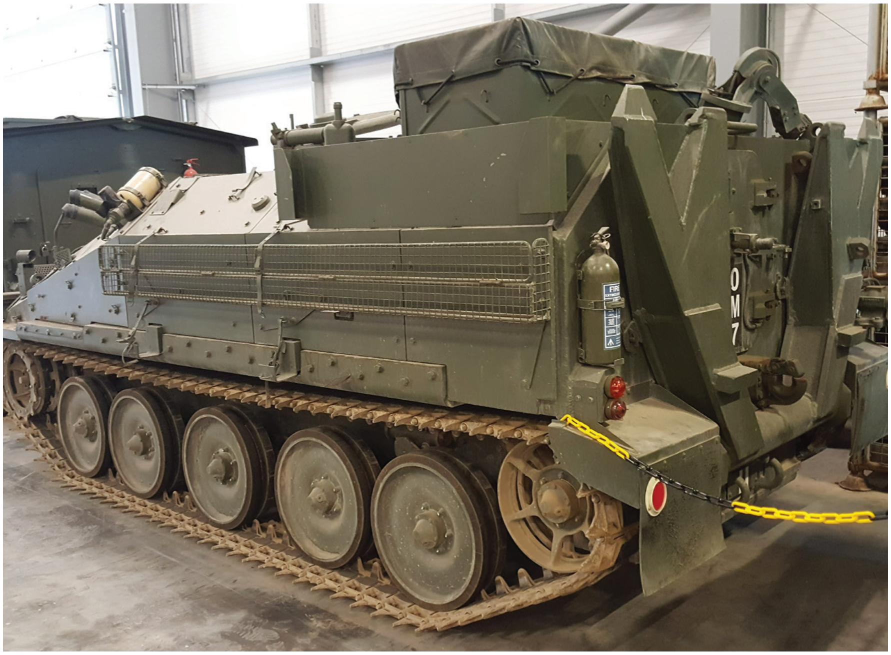
A prototype of a 'flatbed' load carrier variant of CVR(T) called Streaker was also built but never went into production.

OPERATIONAL USE

The first operational use of CVR(T) was in 'CORPORATE', the campaign to liberate the Falkland Islands from the Argentinian occupation. Two standard medium Recce Troops each of two Scorpion and two Scimitar vehicles were dispatched supported by a Samson recovery vehicle. One troop was initially landed to support 40 Commando and the other supporting 3 Parachute Regiment. Throughout the campaign the vehicles undertook a range of tasks including casualty evacuation and fire support roles. The vehicles did undertake air defence tasks which had the effect of forcing aircraft to fly higher and hence be more vulnerable to the Rapier Air Defence System. Three Skyhawk kills were claimed, one of which was very credible. The vehicles soon demonstrated their ability to cope with the difficult terrain and one troop commander reported that when undertaking an escort role for a convoy of BV202 high-mobility vehicles the speed and mobility of CVR(T) was greater. Both troops were given orders to redeploy to

Spartan and Samaritan. (Author's Collection) support the 5th Infantry Brigade at Bluff Cove; the move was expected to take 36 hours but was completed with six hours. The vehicles covered an average of 400 miles each in very difficult conditions of rough or boggy terrain and temperatures down to -15°C. Only one major reliability failure occurred, that of a gearbox which was replaced to enable the vehicle to continue operating. Mobility exceeded expectations and on one occasion a vehicle commander jumped down from his vehicle to sink up to his knees in peat bog. On the occasions when vehicles did get bogged, they were quickly extracted by other vehicles using the kinetic energy towrope system. The Scorpions fired an average of 50–60 76mm rounds and the Scimitars 100–120 30mm rounds. The only operational damage occurred when a vehicle struck a mine and although the vehicle was no longer operational the crew survived with only minor injuries. Although no vehicles received direct hits, mortar or artillery shells exploded within 2m of the vehicles on several occasions with minimal effect. Combat Vehicle Reconnaissance (Tracked) vehicles, carrying troops from 2 Para, were the first British forces to arrive in Port Stanley.





LEFT
FV106 Samson armoured recovery vehicle. (Author's Collection)

ABOVE
Scimitar 2 in 'Theatre Entry Standard' configuration. (Crown Copyright MOD)

Combat Vehicle Reconnaissance (Tracked) vehicles has also seen action in operations in Kuwait, Bosnia, Iraq and Afghanistan. Testament to the original design is the fact that new CVR(T) vehicles, with hulls fabricated using an improved aluminium alloy, were manufactured in 2011 for use in Afghanistan. The so-called 'Scimitar 2' mated a Scimitar turret with a Spartan-based hull giving a vehicle configured to provide significantly enhanced crew survivability in the event of a mine or Improvised Explosive Device (IED) attack.

In 1979 a CVR(T) Mid Life Improvement study was undertaken and this identified a number of potential areas for upgrades and recommended the fitting of a thermal sight to Striker, a laser rangefinder for Scorpion and Scimitar, redesigned tracks to improve reliability and give some mobility benefits, measures to reduce the thermal signature and changes to improve reliability and maintainability; however, none of these measures was implemented at that time.

One major change that was implemented on the majority of CVR(T) platforms was the replacement of the original Jaguar petrol engine with a Cummins diesel engine under the CVR(T) Life Extension Programme (LEP). The use of a diesel engine was mainly driven by a desire to use a common fuel with other armoured vehicles, but it was also seen as providing survivability benefits. Originally three contenders were considered for a re-engine exercise: a Cummins B series engine, a Perkins Phaser and a Puch Steyer M16 TCA. Vehicles were fitted with all three engines for trials purposes; vehicles with the first two engines being tested in 1992 and the vehicle with the third engine type early in 1993. Following the trials, the Cummins engine was selected and subsequently fitted to in-service vehicles.

Another major upgrade was the provision of thermal sights as part of the Battle Group Thermal Imager (BGTI) programme. The use of thermal sights to replace the Image Intensifier system was considered earlier with the TOGS system, as fitted to Challenger, being tested in 1992. The BGTI programme was a broader activity which covered the fitting of thermal sights along with laser rangefinders and a navigation system to a number of CVR(T) and Warrior vehicles. Implementation of BGTI was carried out following user trials of competing systems in May/June 2000. The CVR(T) variants upgraded were Scimitar and the Engineer Recce and Mortar Observation Post (OP) versions of Spartan.

A wide range of additional upgrades and enhancements have been carried out under 'Urgent Operational Requirement' programmes to meet the needs of specific operational deployments; these have included additional armour, improved mine protection and counters to improvised explosive weapons.

Total production for the British Army was 313 Scorpions, 89 Strikers, 691 Spartans, 50 Samaritans, 291 Sultans, 95 Samsons and 334 Scimitars. Combat Vehicle Reconnaissance (Tracked) vehicles have been widely exported and used by a number of countries including Belgium, Botswana, Brunei, Chile, Honduras, Indonesia, Iran, Ireland, Jordan, Latvia, Malaysia, New Zealand, Nigeria, Oman, the Philippines, Spain, Tanzania, Thailand, Togo, the United Arab Emirates and Venezuela. In addition, Australia mounted Scorpion turrets on M113 APCs and Canada mounted them on some of their Cougar armoured cars. Recently Latvia has purchased 120 surplus vehicles from the UK.

FV4333 STORMER

A later variant of CVR(T) was the FV4333. This was developed at MVEE Chertsey following the modification and test of a vehicle based on the FV101 Prototype P11. This had an extra section welded into the hull and an additional wheel station each side in order to demonstrate the basic concept. The design of FV4333, or Stormer, was completed by January 1976 when a Provisional Vehicle Specifications document was issued. It was an enlarged CVR(T) of similar configuration to Spartan but with a longer hull to carry a crew of ten. It had the extra wheel station to maintain the same low ground pressure of the CVR(T) family of vehicles. The width was also slightly increased to accommodate a larger Perkins 250bhp diesel engine which was linked to a modified version of the TN15 gearbox, designated T300. Although considered as a replacement for FV432 it did not initially enter British Army service and the design rights were purchased by Alvis who marketed it for overseas sales, selling it to Indonesia, Malaysia and Oman. The protection levels of Stormer were improved over that of CVR(T) and the vehicle was designed to be fitted with an appliqué armour kit which extended the frontal arc protection levels over the sides; this added about a tonne to the overall weight. Versions of the vehicle with a 30mm gun turret were also designed but it was envisaged that the appliqué armour system would not be fitted to this variant due to the additional weight of the turret. The vehicle could carry a crew of commander, driver and eight other fully equipped soldiers along with enough stores and provisions for a 24-hour mission. Alternatively 1.9 tonnes of stores could be carried.

The key characteristics of Stormer were:

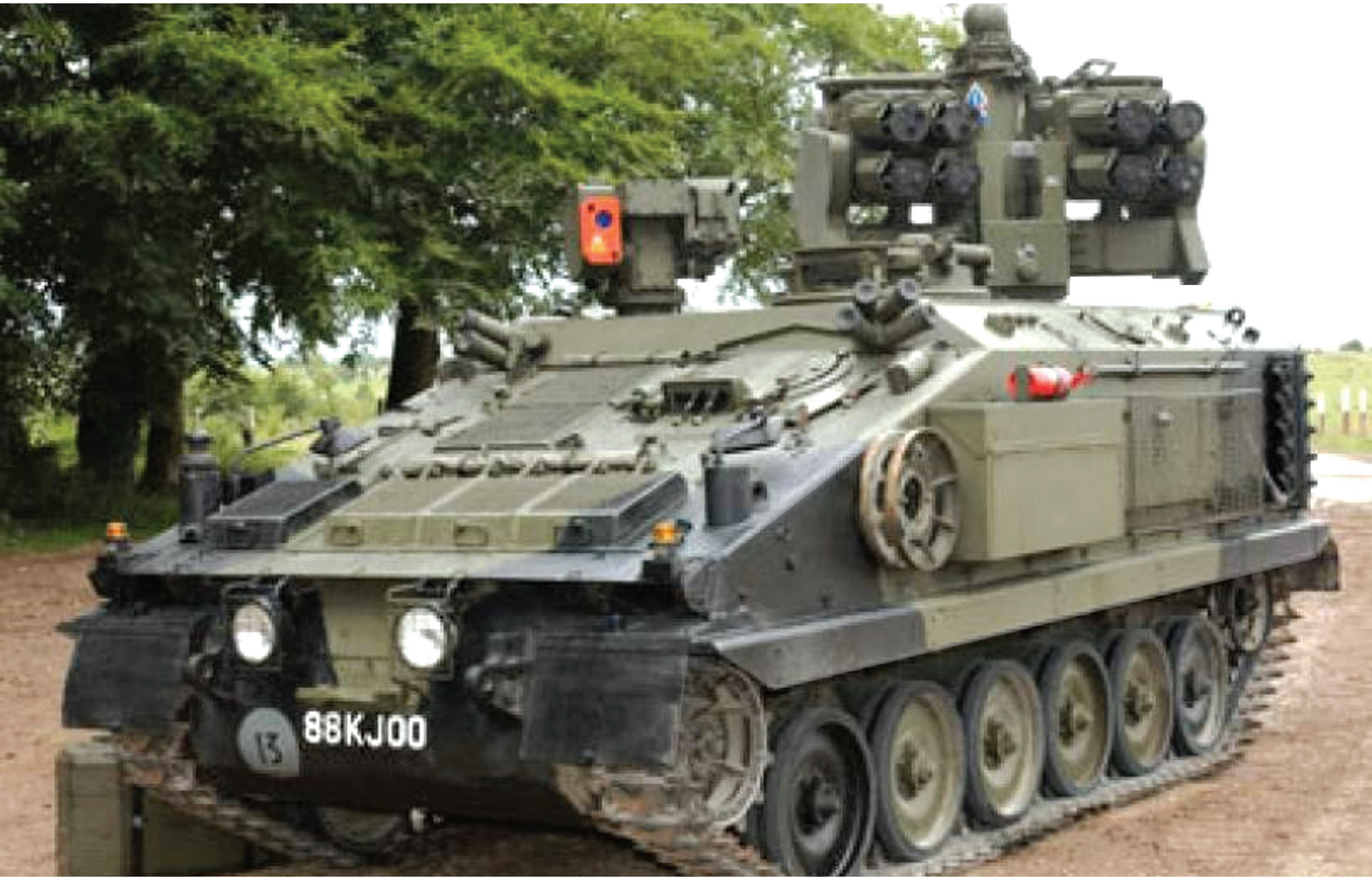
Length: 5.34m
Height: 2.39m
Width without appliqué armour: 2.375m
Width with appliqué armour: 2.65m
Weight, basic vehicle: 8.74 tonnes
Battle weight: 10.64 tonnes

FV4333 was later used as the basis of the self-propelled anti-aircraft system mounting the Shorts Missile Systems (now THALES) Starstreak Anti-Aircraft missile system – called the Stormer HVM (High Velocity Missile). One hundred and fifty-one were procured for British Army service. It mounts an unmanned turret with eight ready-to-fire missiles with a further nine missiles stowed inside. The main dimensions of this vehicle are:

Weight: 13.5 tonnes
Height: 3.40m
Width: 2.80m
Length: 5.60m

It is powered by the Perkins diesel giving a top speed of 80kph and the 328-litre fuel capacity giving a range of 600km. Consideration was given to fitting a Cummins B series engine as used on Shielder (discussed below) along with the improved T303 gearbox for later production vehicles, however, the decision was made not to change the power pack to maintain commonality across the fleet. As well as being supplied to the British Army it was exported to Oman.

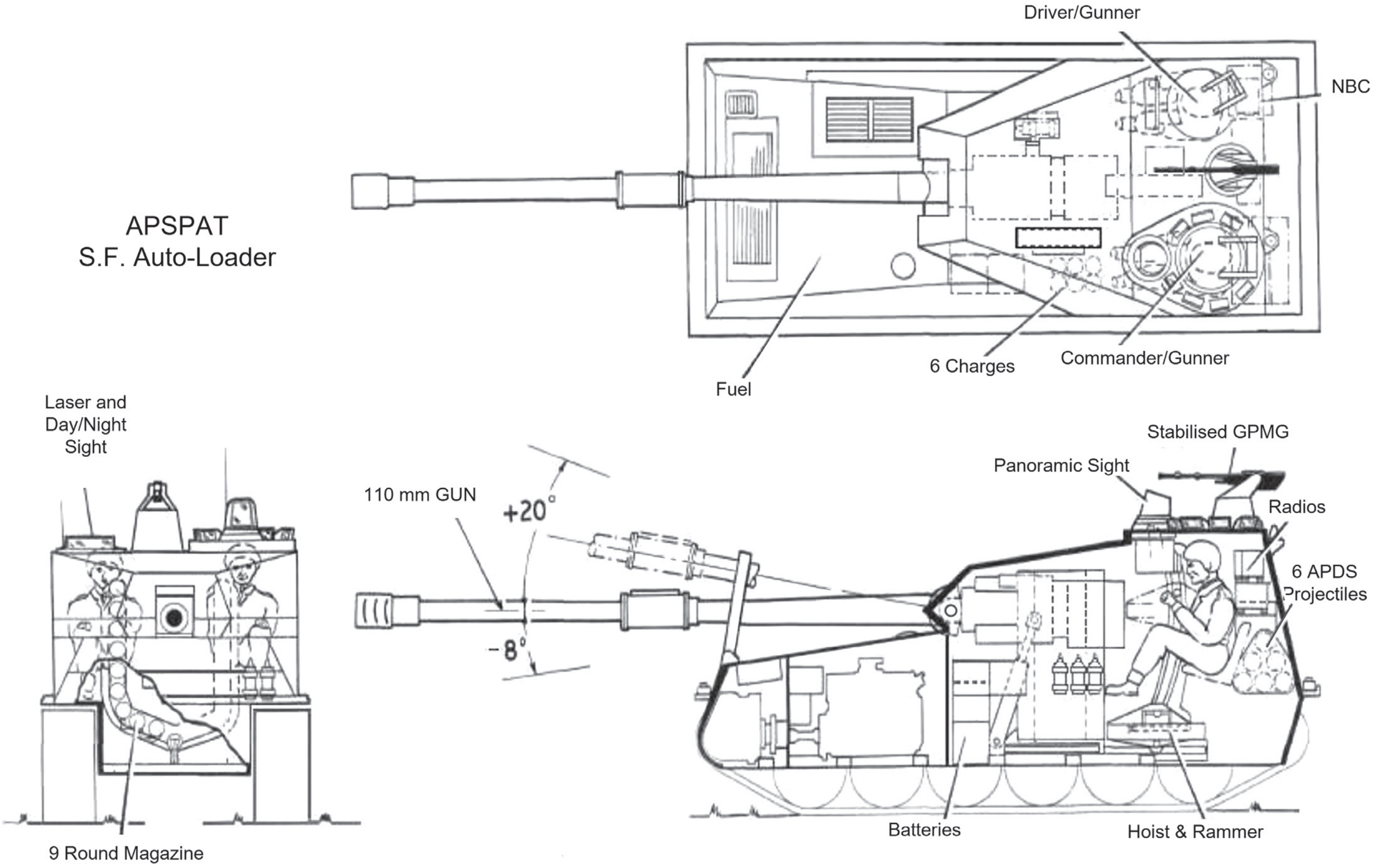
A ‘flatbed’ version of Stormer was used as the platform for scatterable mine-dispensing systems. The first such system to be fielded was procured as an Urgent Operational Requirement for Operation *Granby*. Six were procured which mated the Stormer with the French Minotaur system manufactured by GIAT. The Minotaur mine launcher system consisted of six launcher modules, each with 100 mines. All 600 mines could be dispensed



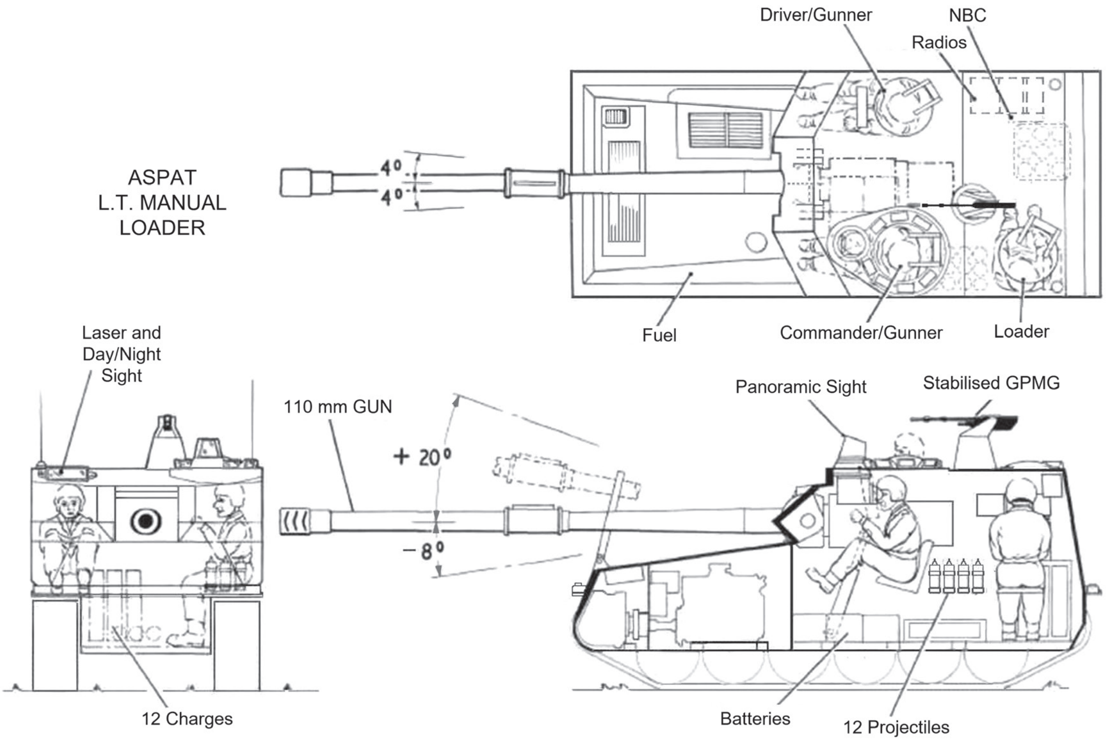
Stormer HVM (High Velocity Missile) with the Starstreak Anti-Aircraft missile system. (Crown Copyright MOD)

in less than five minutes and the dispersion pattern of the mines was intended to generate a minefield 1,200m long and up to 300m wide. In addition to the launchers the vehicle was fitted with an inclination sensor (which inhibited mine launch if the vehicle was at an unsafe angle), GPS, a PRC 352 radio and a pintle-mounted GPMG for self-defence. The vehicle was 6.29m long, 2.70m wide and 2.28m high – which made it slightly longer and wider than the standard Stormer. It weighed 14 tonnes and had uprated torsion bars to cope with the increased weight. The same Perkins T6 engine and T300 gearbox was used, giving a top speed of 70kph. The T300 gearbox provided seven gears in both forward and reverse. Although the basic 'flatbed' platform was based on the FV4333 it was not, at that time, a fully developed production variant and so this had to be designed and manufactured, along with the installation kit for the mine-dispensing system, in time to be deployed on operations; this was achieved in just 14 weeks.

Later there was a formal competition for an FV4333-based VLSMS (Vertical Launch Scatterable Mine System) called Shielder; requirements for which were defined in SR(L) 4020. A Competitive Evaluation Phase was carried out to assess the Minotaur System and the US Alliant Techsystems 'Volcano' system. The competition concluded in early 1994 with the Alliant system being selected. A contract was placed in November 1995 for full development and delivery of 29 systems and 63,300 mines; the order was increased to 30 vehicles and 79,200 mines in October 1998. The vehicle entered service in 1999. Shielder was fitted with a Cummins B series engine in place of the Perkins engine used on previous FV4333 variants; the main driver for this engine change was being able to meet the Euro two emission regulations, even though exemptions can apply to military vehicles. The revised T303 gearbox was developed to improve reliability.


Driver/Gunner
NBC
APSPAT
S.F. Auto-Loader
Fuel
6 Charges
Commander/Gunner
Laser and Day/Night Sight
110 mm GUN
+20°
-8°
Panoramic Sight
Stabilised GPMG
Radios
6 APDS Projectiles
9 Round Magazine
Batteries
Hoist & Rammer

CVR(T) based Air Portable Anti-Tank system with autoloader. (Crown Copyright MOD)


Driver/Gunner
NBC
Radios
ASPAT
L.T. MANUAL
LOADER
4°
4°
Fuel
Commander/Gunner
Loader
Laser and
Day/Night
Sight
110 mm GUN
+ 20°
– 8°
Panoramic Sight
Stabilised GPMG
12 Charges
Batteries
12 Projectiles

CVR(T) based Air Portable Anti-Tank system, three-man crew. (Crown Copyright MOD)

One Alvis private venture version of Stormer, for which only a prototype was built, was a bridge layer mounting a US lightweight bridge.

AFV FOR THE 80S STUDY: STAGE 3 AIRBORNE SELF-PROPELLED ANTI-TANK

As discussed, the AFV for the 80s study was a comprehensive review of armoured vehicle requirements covering heavy MBT (Stage 2), medium AFV (Stage 1) and SPAT systems (Stage 3). The SPAT system study reported in January 1973 and included concepts for an air-portable SPAT, (ASPAT), based on CVR(T) components. Protection levels were to be similar to CVR(T) and the estimated weight for the concept designs was in the region of 12–13 tons. Three variations of the design were considered:

1. ASPAT semi-fixed gun with manual loader, crew of three;
2. ASPAT semi-fixed gun with autoloader, crew of two;
3. ASPAT limited traverse gun with manual loader, crew of three.

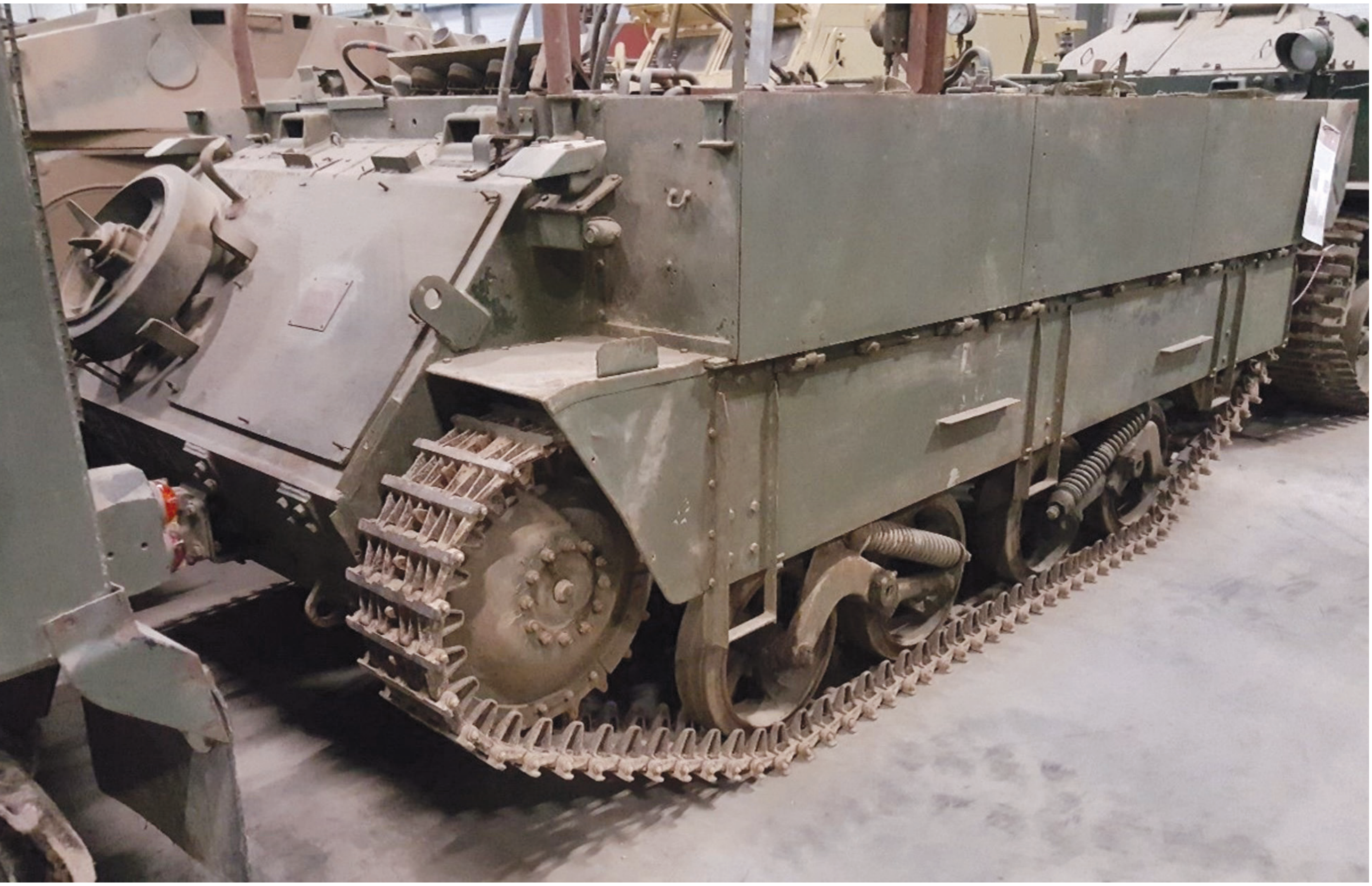
The semi-fixed gun solutions had the weapon free to elevate but fixed in azimuth, requiring the vehicle to steer to aim. The limited traverse solutions again relied on the vehicle turning for the course aiming of the gun but provided a traverse of +/-4 degrees for fine aiming. Both 90mm and 100mm main armaments were considered but the final concepts used the same 110mm gun as proposed for FMBT. A range of alternative engines was considered including the Jaguar engine as fitted to CVR(T) rated at 190hp, a V12 Jaguar engine rated at 240hp and a Rolls-Royce V8 engine rated at 280hp. The basic dimensions of the ASPAT variants were: length 5,005mm, width 2,180mm and height 2,603mm. The weight varied from 12.3 tons for the semi-fixed gun with manual loader, 12.6 tons for the semi-fixed with autoloader to 13.3 tons for the limited traverse variant. The semi-fixed variants both carried 15 rounds with the autoloader variant having nine of those stowed in the autoloader ready for use. The limited traverse version carried 12 rounds.

Later studies were carried out into the potential of variants of CVR(T) armed with even larger-calibre weapons. One study, which reported in June 1979, looked at the feasibility of mounting a low-velocity 120mm gun firing a HEAT round at 1,000m/s on a CVR(T)-based vehicle.

CARRIERS AND ARMOURED PERSONNEL CARRIERS

OXFORD CARRIER

From the early post-war days of the establishment at Chertsey there had been activities to develop concepts and designs for tracked armoured personnel carriers to take over the role of the World War II Universal Carriers and ‘Kangaroos’ (the name given to tanks with their turrets removed and used to carry infantry). An APC version of the FV300, designated FV310, was planned and APCs based on the Churchill (FV3904) and Conqueror were considered but not taken forward. In 1944 development had started of a new Universal Carrier called the CT20 or Oxford Carrier. Based on a 1943 specification it was larger than the previous universal carriers; 4,496mm long,



Oxford carrier in the Conservation Hangar at the Bovington Tank Museum. (Author's Collection)

2,299mm wide and 1,600mm high. It weighed 6 tons and was powered by a Cadillac V8 engine of 110hp coupled to a US transmission and Cletrac steering. It was designed to tow weapons such as the 6-pdr and 17-pdr guns and carry crew and ammunition. A driver, commander and six additional men could be carried. Hinged pannier side plates were designed to be removed as required, for use as shields for the towed guns when emplaced. The overall layout of the CT20 was similar to that of the Universal Carrier but with four, rather than three, road wheels. The hull front was sloped and the driver and commander were provided with periscopes to allow them to operate in a full head-down manner. Space for the other six passengers was provided behind the driver's position. There was no overhead armour protection but provision was made for a canvas tilt to provide protection from the elements. The Fighting Vehicle Development Department (FVDD), as the Chertsey establishment was then called, built a mock-up of the fighting compartment on an Alecto chassis along with a mock-up of the chassis for design approval. Prototypes were then built by the MG Motor Company at Abingdon in late 1944 and these undertook user trials until July 1945. The CT20 was displayed as the future improved carrier at the July 1946 equipment exhibition at Chertsey. At that event it took part in a mobility demonstration alongside a German 8x8 armoured car and a Coventry armoured car. Testing went on at Chertsey throughout the late 1940s and trials included towing a mortar baseplate (1947) and 25-pdr gun, 25-pdr gun limber and the 17-pdr anti-tank gun (1949). The testing highlighted defects with the Cadillac engine and the suspension. In view of the shortcomings of the CT20, FVDD worked on improvements which resulted in the development of the CT25, which had a Rolls-Royce engine and improved suspension. The improved automotives and running gear were designed to allow the extra weight of overhead protection to be carried; this consisted of hinged plates that folded up in a configuration that was then used on the Cambridge Carrier. As well as supporting the further development of the CT20, Rolls-Royce also used some Oxford Carriers as test beds for developing their B Range of military engines and one modified vehicle was fitted with a hydraulic transmission. In addition, they proposed a version of the CT20 with improved armour and mine protection and carried out some rig trials.

Around 400 Oxford Carriers were built and it was issued to BAOR and used in action in Korea, remaining in service until 1964.[15] In Korea the Black Watch used them, with trailers, for ferrying ammunition across the difficult terrain. One vehicle was sent to Australia for trials as a potential replacement for the LP2A, which was a locally produced version of the Universal Carrier.

CAMBRIDGE CARRIER

By 1948 the decision had been made to procure a new vehicle rather than try to further enhance the CT25 design, hence development of the FV401, the Cambridge Carrier, started; a vehicle also sometimes referred to as the ‘Universal Carrier No 4’. The requirement for FV401 covered a wider range of roles than previous carriers, including:

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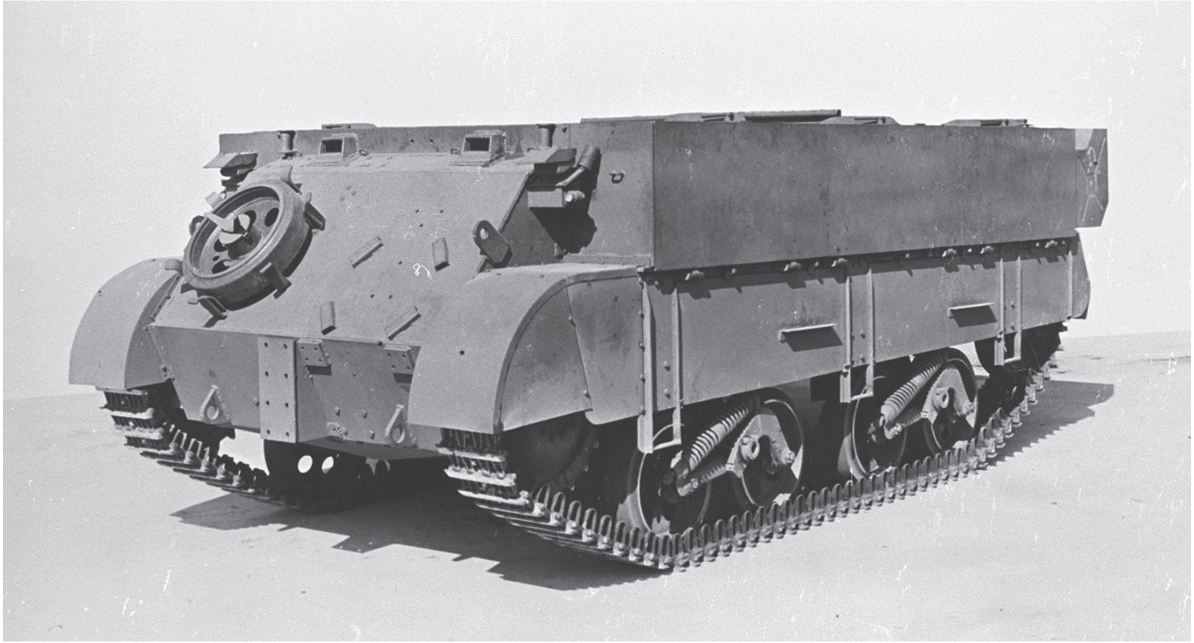
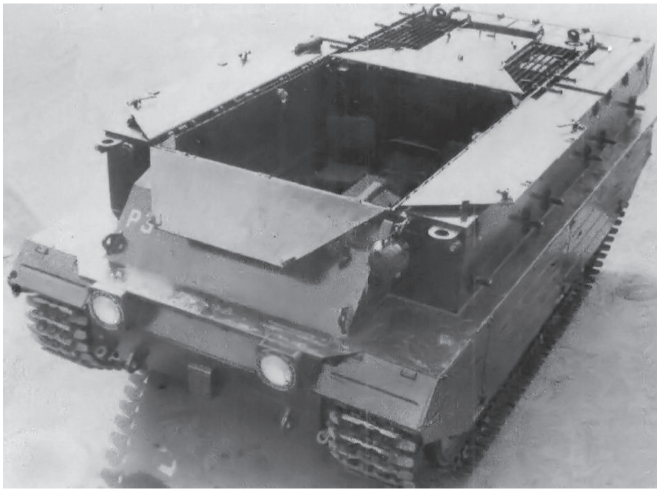
[15] An Oxford Carrier is on display in the ‘Victorious Fatherland Liberation Museum’ in Pyongyang, North Korea.



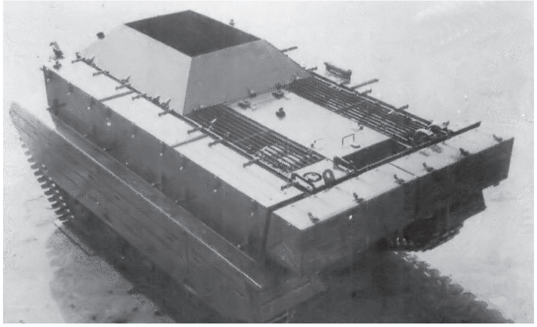
Oxford Carrier, 400 were built with some seeing service in Korea. (The Tank Museum, Bovington)

FV402: Artillery observation post
FV403: Light anti-tank gun tractor
FV404: Charging vehicle
FV405: Light general purpose carrier
FV406: Command vehicle
FV407: Air cooperation signals vehicle – called Tentacle
FV408: Ambulance
FV409: Gun position officer/command post



FV401 Cambridge Carrier with panels providing limited overhead protection folded down. (Crown Copyright MOD)

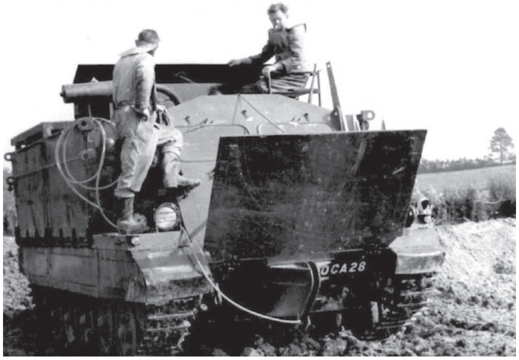
A reconnaissance version was also proposed. Unlike the vehicles it was intended to replace, it had a requirement from the beginning for overhead protection. A pilot model was built by Rolls-Royce in 1950. It was slightly larger than the Oxford Carrier with the length increased to 4,693mm to accommodate the larger B30 engine linked to a Hobbs transmission. An Oxford Carrier was used as a test bed to test the engine and transmission. The



ABOVE
Rear view of FV401 Cambridge Carrier with the overhead protection in place. (Crown Copyright MOD)

height increased to 1,635mm with the provision of roof protection. The width increased to 2,540mm to accommodate 457mm-wide tracks which provided a significant reduction in ground pressure compared with the 267mm-wide tracks on the CT20/25. In a departure from previous carriers, torsion bar suspension was fitted. The basic armour was 10mm thick and the unladen weight was 6.5 tons with a payload of 1.1 tons. The B30 engine was coupled with a Daimler-Wilson transmission giving a top speed of 35mph (56kph). In addition to the pilot model six further prototypes of the basic carrier were completed, the first three by April 1953 and the other three by June 1953 with prototypes 1 and 2 delivered to the infantry school for user trials. Five prototypes of the Observation Post vehicle variant (FV402) were also built and were delivered between June and September 1953. In 1955 one FV402 prototype was sent to the 3rd Regiment Royal Horse Artillery in Tripolitania in Libya for hot weather trials, however, these were terminated in December of that year. A number of role-specific conversion kits were designed, including an equipment-towing kit, a mortar carrier kit, a signals kit and a flotation kit. FV401 undertook extensive trials including mine impact trials in 1956 and swimming trials, but did not enter production, despite a potential order of 482 from Australia. The Canadians also expressed an interest in an updated Carrier and in September 1951 tabled an outline specification to a joint UK, US and Canadian meeting. The requirement called for a vehicle of similar dimensions to the FV401 to cover a number of roles including stores movement, casualty evacuation, a wireless station and a tactical mobility vehicle. The required payload was 1.5 tons and a crew consisting of a driver plus up to five others. The proposal was not taken forward as a joint requirement. In 1949 when development of the Cambridge Carrier was starting, consideration was given to a 'noiseless' tracked reconnaissance vehicle based on the FV400. It was to be a 9.1-ton vehicle with a crew of three and mounting a 2-pdr anti-tank (AT) weapon but no development work started.

BELOW
FV420. This vehicle is pictured during river exit trials in support of FV434 development with additional winch and earth anchor equipment fitted. (Crown Copyright MOD)



FV420

FV420 stowage trials with BAOR. (Crown Copyright MOD)

In 1954 a requirement was formulated for an unarmoured tracked vehicle 'for use by the Army to meet the tactical requirement for continuous cross-country movement under conditions of nuclear warfare'; this was intended as an alternative to conventional wheeled trucks with their limited mobility. Concept work was undertaken between June 1954 and July 1955 and resulted in a mock-up of what was to be designated the FV420. To minimize development time and cost the concept was based on FV401 running gear which was strengthened and had an additional wheel station added. As it was intended as a replacement for wheeled vehicles an emphasis was placed on reliability and ease of maintenance. Easy access was provided for the engine which was a Rolls-Royce B80 Mark 2f unit generating 160 BHP at 3,750rpm. Steering was by a Cletrac steering unit based on FV401 but the gear ratio in the final drive was reduced to reflect the required lower speed and increased weight of FV420. The vehicle was designed so that the whole engine, transmission and cooling system could be withdrawn through the vehicle rear plate on a common sub-frame.

The initial concepts covered a cargo/personnel carrier to transport 5 tons of cargo or 20 fully equipped soldiers, a command version, an armoured Royal Engineer section vehicle and an armoured REME fitter's vehicle. The armoured variants were planned to have 14mm armour plate all round but no roof protection. The estimated unladen weight was to be 8 tons for the unarmoured version and 10¼ tons for the armoured version.

A contract was placed with GKN Sankey for the build of four prototypes and ten trials vehicles, which were delivered in 1958. By this time the required family of vehicles had been formalized as:

FV421: Cargo carrier with a payload of 5 tons
FV422: Personnel carrier
FV423: Command vehicle
FV424: Royal Engineer vehicle
FV425: REME vehicle
FV426: Missile launcher

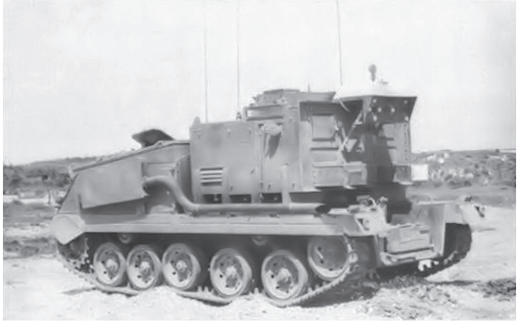
The designation FV421 had been informally used in 1955 for a School of Tank Technology 'Tank Technology Officer' course design for a light mobile anti-tank system mounting a weapon similar to the 120mm BAT recoilless gun. Called 'Badger' it was not an endorsed FVRDE project.

The FV420 prototypes delivered by GKN Sankey included the cargo and troop-carrying variants. A key feature of the FV421 was the design of the panniers which allowed rapid loading and unloading of stores and ammunition in its intended resupply role. In 1959 a prototype was trialled by BAOR in a configuration that carried 40 boxes of .30 Browning machine-gun ammunition, 180 rounds of 20-pdr ammunition and 24 rounds of 120mm ammunition. The stowage was then modified to carry 134 105mm rounds in place of the 180 20-pdr rounds. One vehicle, 00 CA 30, was sent to the Middle East trials unit in 1958 for desert trials. In January 1960, FVRDE issued an interim trials report on FV421 with a final report in August 1962, however, user interest declined due to concerns about the lack of armour protection.

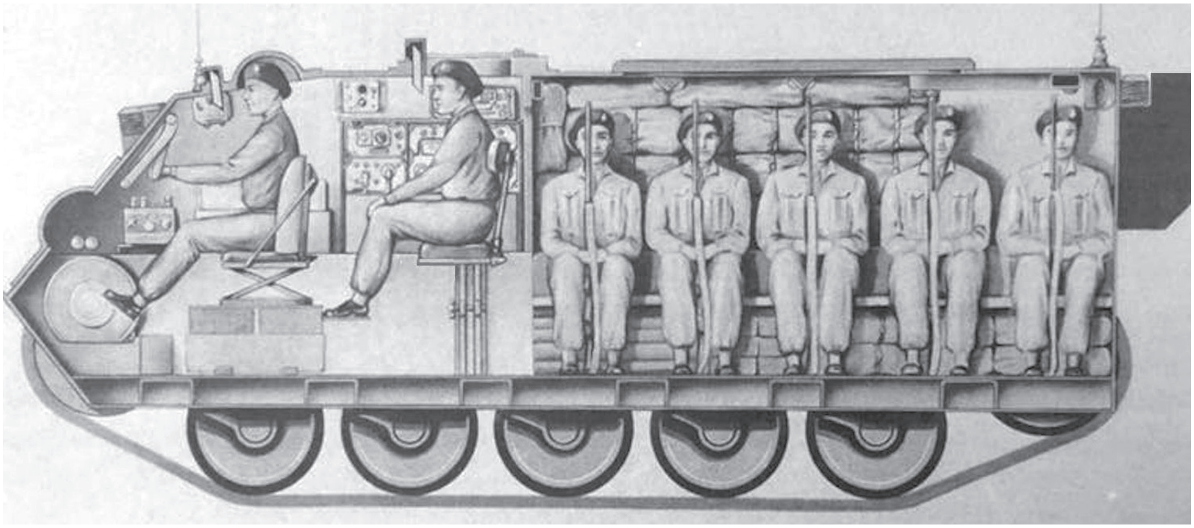
The FV426 was to be a launcher vehicle for the Orange William Anti-Tank Missile, planned to provide a lighter alternative to the FV4010, which was also being developed at that time. Two prototype FV426s were planned to be delivered in April 1960 but the Orange William project was cancelled in 1959.

FV420 was designed to be amphibious and this was demonstrated in trials off Chesil Beach in 1960. A prototype FV420 (OO CA 28) was later used by MEXE for trials into river exiting to support winch development for FV437, exploiting the similarity between the vehicles. During these trials a prototype earth anchor was tested that eventually evolved into the design of the production item fitted to the Combat Engineer Tractor. One prototype (OO CA 25) was later used for trials into the impact of mine blast on lightweight tracks.

FV431 prototype, fitted with a crew pod for a crew human factors trial. (Crown Copyright MOD)



In 1961 one FV420 prototype had its superstructure cut down and a 105mm gun mounted on it for firing trials. This was undertaken in support of the AVR programme which, as mentioned above, included concepts for a tracked vehicle mounting a 105mm gun. The FV420 trials were carried out to test the viability of the 105mm gun on a light chassis that aimed to meet the 14-ton weight limit specified in GSR 1006 and 1010.

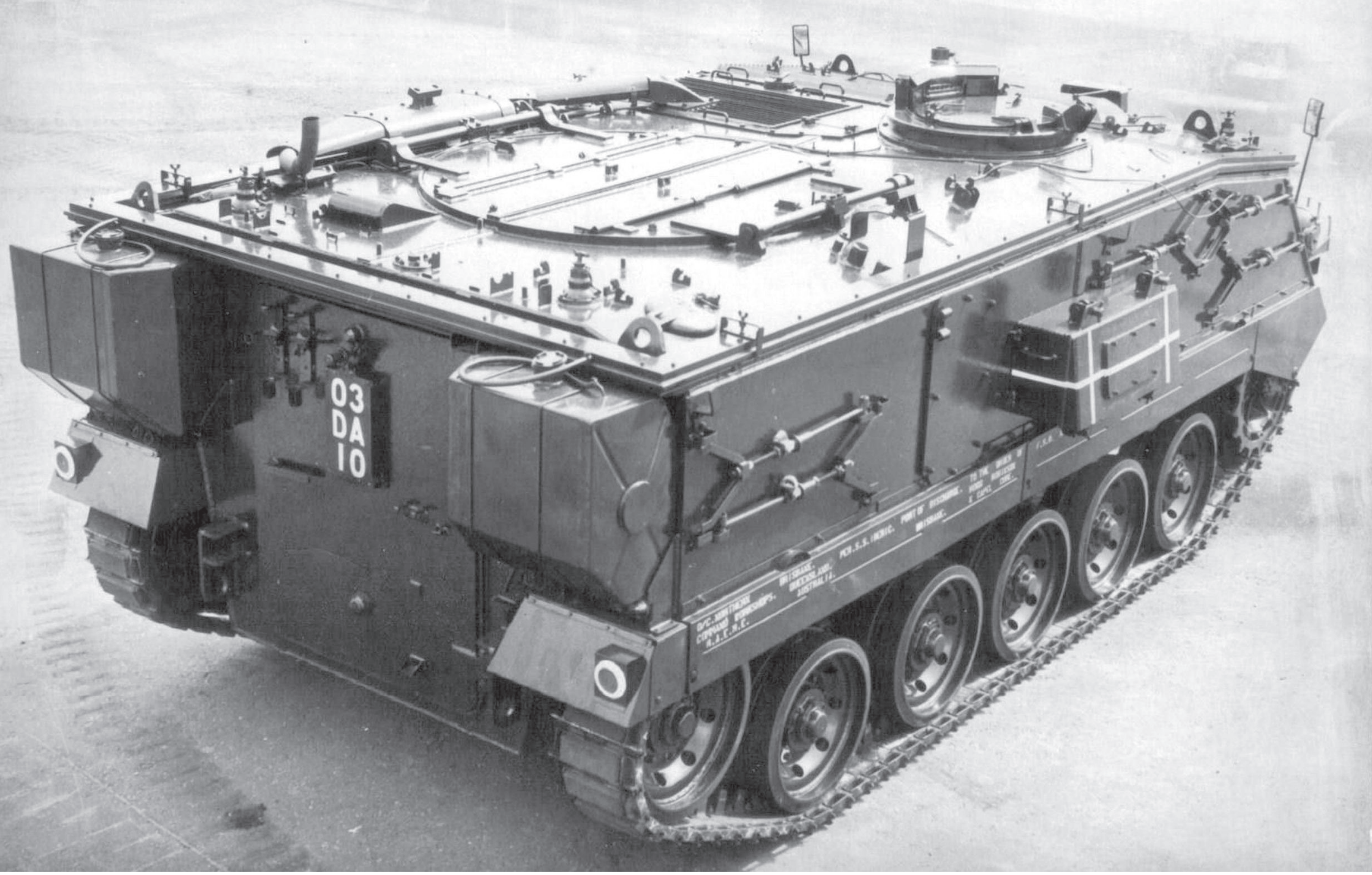


FV432 cross dection showing driver, commander and dismounts. (Crown Copyright MOD)

FV432

The Army then drew up a requirement for a fully armoured troop carrier and so by 1959 the FV420 design was being evolved into what became the FV432. Being based on the FV420 many design features of FV432 were taken forward from that vehicle and the Cambridge Carrier that preceded it, including the torsion bar suspension and running gear. The FV420 was used as a test bed for proving FV432 components including the development of the Cletrac transmission. Initially control of the brakes on FV432 was by hydraulics, but this gave rise to problems and so the hydraulics were replaced by a mechanical linkage system. The detailed design of FV432 was undertaken by GKN Sankey who built four prototypes. These were followed by 20 pre-production vehicles for user trials, 13 built by GKN and the other seven by the Royal Ordnance Factory. By May 1962 five of these prototypes were with BAOR for user trials, four APC variants and one command variant. A BAOR trials report stated that the vehicles were 'well-liked by crews' and the significant improvements in mobility compared with the Saracen were of particular note. The user trials were seen as being successful with only minor reliability issues involving tracks and hydraulic fan drives needing to be addressed.

FV432 prototype undertaking user trials with BAOR. (Crown Copyright MOD)



FV432 Mark 1 in pristine condition. (Crown Copyright MOD)

FV432 being used for training on Salisbury Plain. (Crown Copyright MOD)

Unlike previous tracked armoured personnel carriers, FV432 was designed for the cold war battlefield with a fully enclosed and armoured crew compartment and an NBC overpressure protection system. Extensive technical and user testing followed including hot climate habitability trials in Aden in October 1961 with prototypes P2 and P3. In 1962 a prototype was sent to the Army Design Establishment in Australia for testing. Following formal user trials and acceptance GKN Sankey was awarded a production contract in 1962 and around 3,000 vehicles were built between 1963 and 1971. The first 599 vehicles were manufactured as Mark 1s with the B81 petrol engine. The remaining were Mark 2s fitted with the K60 diesel engine which was introduced from mid-1965. An improved ventilation system was introduced during the production of the Mark 2 after the first 280 vehicles, and subsequent vehicles were designated the Mark 2/1. The vehicle hull was manufactured from armour grade steel and has the engine at the front left side of the vehicle with the transmission across the front. The driver and commander sit in tandem alongside the engine compartment with the crew or equipment compartment towards the rear. A large circular hatch is provided in the crew compartment roof, which can be used as a mortar hatch and a single door in the hull rear. It has five road wheels per side mounted on torsion bar suspension. The armour steel hull on the basic vehicle provides protection against small arms and shell splinters. As well as the commander and driver ten dismounts can be accommodated on bench seats running down either side of the vehicle. These fold up to allow 3.6 tonnes of cargo to be carried. The commander's cupola was designed to mount a General Purpose Machine Gun or modified Bren gun. The vehicle was designed to swim by raising a flotation screen and fitting an exhaust extension and as part of the BAOR user trials in May 1962 swimming trials were carried out on the Wesser. Most vehicles still in service have had the flotation screen removed.

The intention had been to call the FV432 'Trojan', but this suggestion was dropped after objections to the use of that name by the Trojan car company; however, FV432 has carried on in service long after the Trojan car company ceased making cars in 1974 and the name was subsequently used for the Trojan Engineer tank.

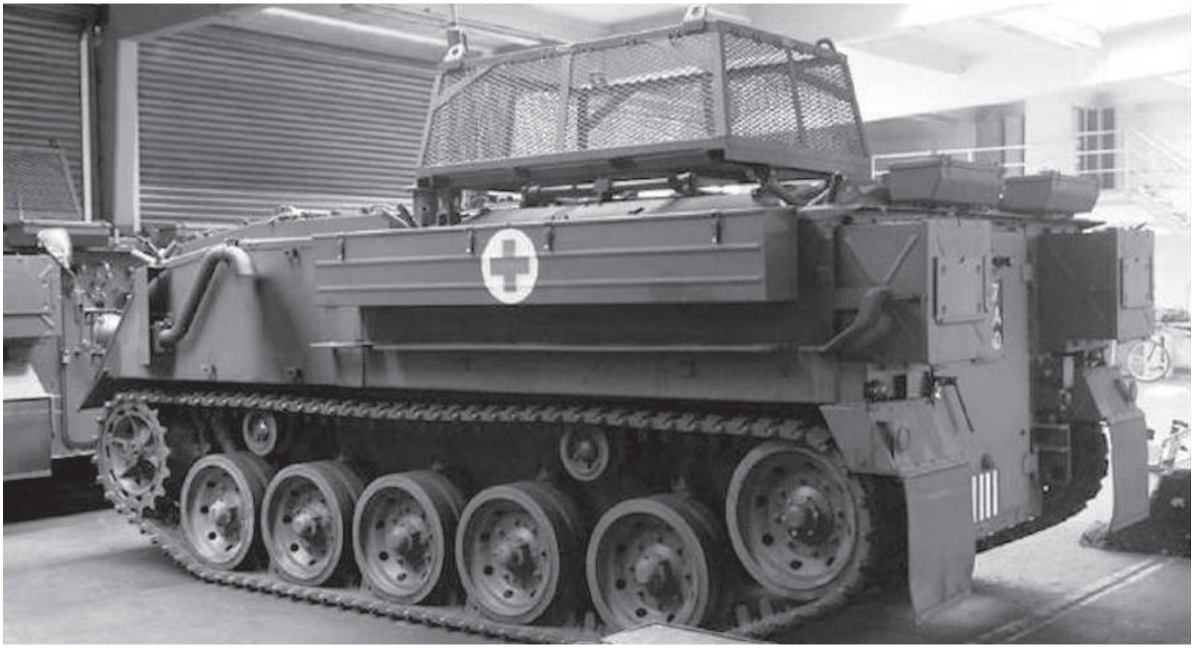
FV432 was designed to be the basis of a family of vehicles which included:

FV431: Armoured load carrier (Trident)
FV432: Armoured Personnel Carrier (APC)
FV433: Abbot 105mm SP gun
FV434: Armoured repair vehicle
FV435: Wavell communications vehicle
FV436: Green Archer radar
FV437: Pathfinder vehicle
FV438: Swingfire missile launcher
FV439: Signals vehicle

All of these variants went into production apart from the FV431, FV436 and FV437 which only reached the prototype stage. Completed in 1960 the FV431 prototype was actually the first of the FV430 series of vehicles to be delivered, but it did not enter production because it was decided that its intended role could be covered by Stalwart, which was due to enter service around the same time. However, the one prototype FV431 was retained as a trials vehicle.

In addition the variants listed above the basic FV432 can be configured to undertake a number of roles including:

- Ambulance, which can carry four stretcher or two stretcher and five seated patients;
- Command with map boards, additional radios and lighting and provision for a 3.6m x 2.7.m penthouse tent;
- Artillery Battery Command vehicle with the Field Artillery Computer Equipment (FACE) and sound ranging system;
- 81mm L16A1 mortar carrier. The mortar can be dismounted or fired from the vehicle through the large roof hatch for which it is mounted on a turntable for traversing. The normal operating mode is to fire the mortar over the rear 180-degree arc of the vehicle. The normal crew in this role is six and stowage for 160 rounds is provided, as a result the fully loaded the vehicle is over 1 tonne heavier than a basic FV432;
- 84mm Carl Gustaf anti-tank weapon carrier, with a mounting bar across the roof to enable the weapon to be fired from the vehicle;
- Wombat recoilless anti-tank gun carrier. The weapon could be fired from the vehicle, for which it was mounted at the front of the large roof hatch, or dismounted. The vehicle crew was four and 14 rounds of ammunition could be carried;



FV432 in ambulance configuration. (Crown Copyright MOD)

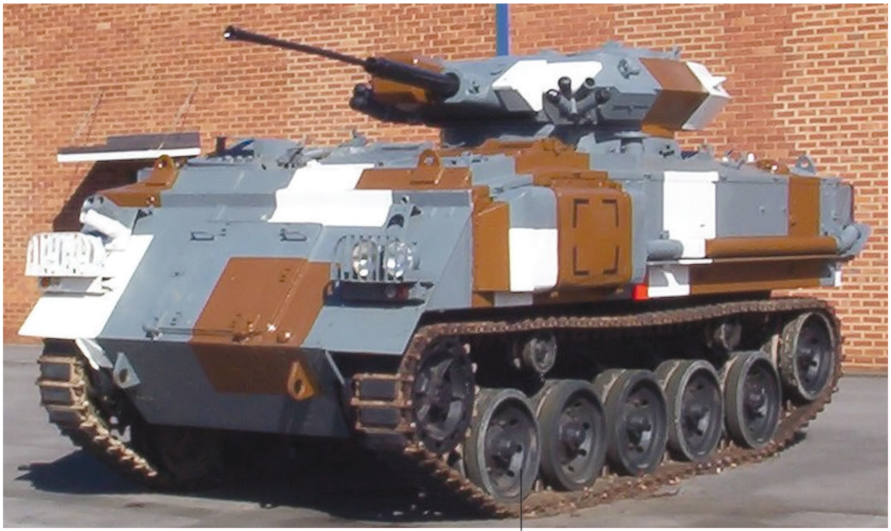
- Milan team carrier with a single vehicle able to carry four two-man teams and up to 48 missiles;
- Recovery vehicle with winch installed in rear troop compartment driven by a power take-off (PTO) from the engine. A modified door and earth anchor could be fitted as part of the modifications. The winch has a 6.6-tonne pull and a maximum pull of 18.3 tonnes using three-part tackle;
- Bar mine layer or Giant Viper towing vehicle.

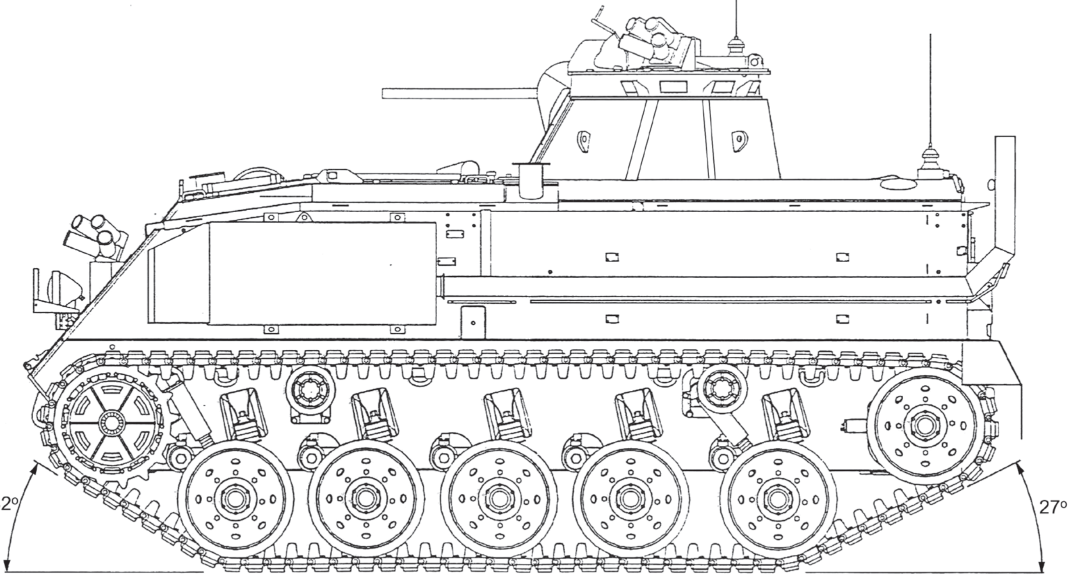
Although the basic vehicle has remained largely unchanged during its life a number of additions and modifications have been introduced on some vehicles. Fox turrets were fitted to some FV432s; however, trials carried out by the Infantry Trials and Development Unit highlighted a number of limitations with the installation and so only nine vehicles were modified for use by the Berlin Brigade. More successful was the development of a small GPMG turret which was fielded on some vehicles from 1976 onwards. A lightweight GPMG turret was also developed by Peak Engineering but only used in trials. Another version of FV432 that was suggested, but never taken forward, mounted a breach-loading mortar in a turret to overcome the issues associated with the lack of overhead protection for the basic mortar version when in use with the hull roof hatches open.

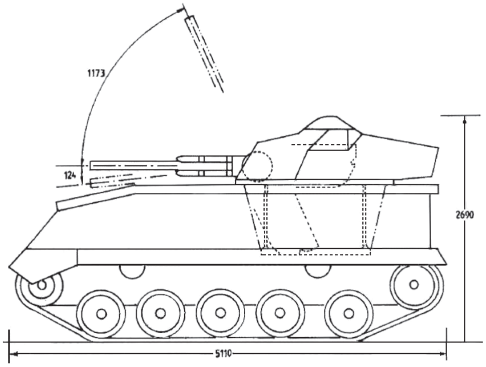
RIGHT
FV432 fitted with a Fox turret in Berlin Brigade camouflage colours. (Author's Collection)

BELOW
Future Light Armoured Vehicle Study scheme for an improved FV432. (Crown Copyright MOD)

BOTTOM
FV432 with mortar turret. (Crown Copyright MOD)

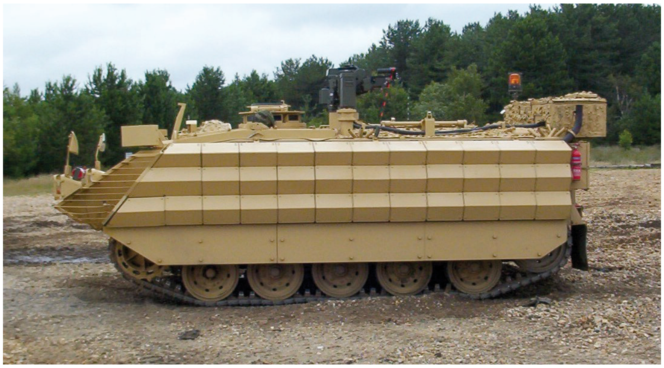






Schemes to up-armour FV432 and increase self-protection firepower were considered as part of the Future Light Armoured Vehicle study described in a later section, however, the resulting extra weight meant that significant upgrades would have been required for the automotive and suspension systems and so the proposals were not taken forward.

In 1974 MVEE reviewed alternative engines for FV432 with the Cummins VT555, GM 6V53T and Perkins TV8 640. The latter was assessed as the easiest to



FV432 'Bulldog' with additional armour. (Author's Collection)

retrofit but no programme to replace the engine was carried out at that time.

FV432 is still in service over 50 years after the original design and a number have been converted to the latest operational version, called Bulldog. This was developed specifically for the Iraq campaign, and has significant survivability enhancements including a comprehensive appliqué armour fit, the basic solution for which was developed by the MOD Defence Science and Technology Laboratory. To cope with the extra weight a new power pack was installed in Bulldog consisting of a Cummins 6B250 engine linked to an Alison X2004C gearbox. The gearbox is similar to that used on Warrior and so the conversion included an upgrade of the driver's controls to a similar set-up to Warrior. BAE Systems, which by this stage was the design parent for FV432, designed a hybrid electric drive solution for FV432 and Bulldog in which an electric motor could provide additional power into a mechanical transfer box to boost performance when needed. However, this was not taken forward.

The only other nation to field FV432 was India which purchased 24 to act as Battery Command vehicles to support the FV433 Abbots also in service.

FV433 ABBOT

Abbot was a 105mm self-propelled gun. After a number of aborted self-propelled gun projects this was the first vehicle to enter service that had been specifically designed as an SP gun as opposed to previous vehicles that had been modifications of existing vehicles. It was a much-needed replacement for the significant number of towed artillery systems in service at the time.

The design was developed at Chertsey and Vickers was appointed as the design parent. Six prototypes of the FV433 Abbot 105mm Self-Propelled Gun were constructed with the first being delivered in 1961. Although it had been decided that production vehicles would be fitted with the Rolls-Royce K60 engine, all the prototypes were fitted with the B81 petrol engine. After some delays user trials of Abbot started in March 1962 and

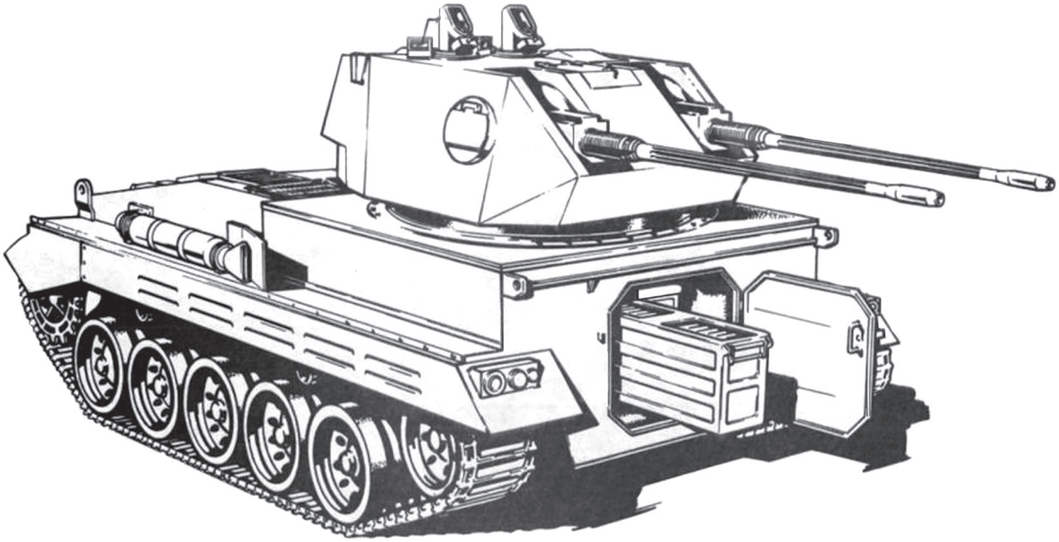
Abbot with the 105mm gun at maximum elevation. (Crown Copyright MOD)

acceptance for service, subject to some design changes, was given in a minute dated 5 February 1963. The main design changes related to ammunition stowage and sights. A significant redesign was required to accept the new engine as the engine compartment was lower and longer than that on FV432. Prototype W2 was reworked for automotive trials with the new engine at FVRDE. Subsequently prototypes W1, W3 and W6 were also reworked for further user trials to assess performance with the new engine and the effectiveness of the other design changes; but due to delays these trials did not begin until production had started, resulting in early production vehicles being modified to meet the final agreed build standard. Production vehicles were manufactured at the Vickers Elswick factory between 1964 and 1967.

Abbot had a front-mounted engine with the driver alongside. The rear half of the vehicle was taken up by the turret and there was an access door at the rear of the hull. The hull was lower than that of FV432 but Abbot used many of the same sub-systems and components including the engine, gearbox and running gear. Like FV432 it was fabricated from armour grade steel. In service Abbot equipped the Close Support Field

FV433 Abbot in travelling configuration. (Author's Collection)

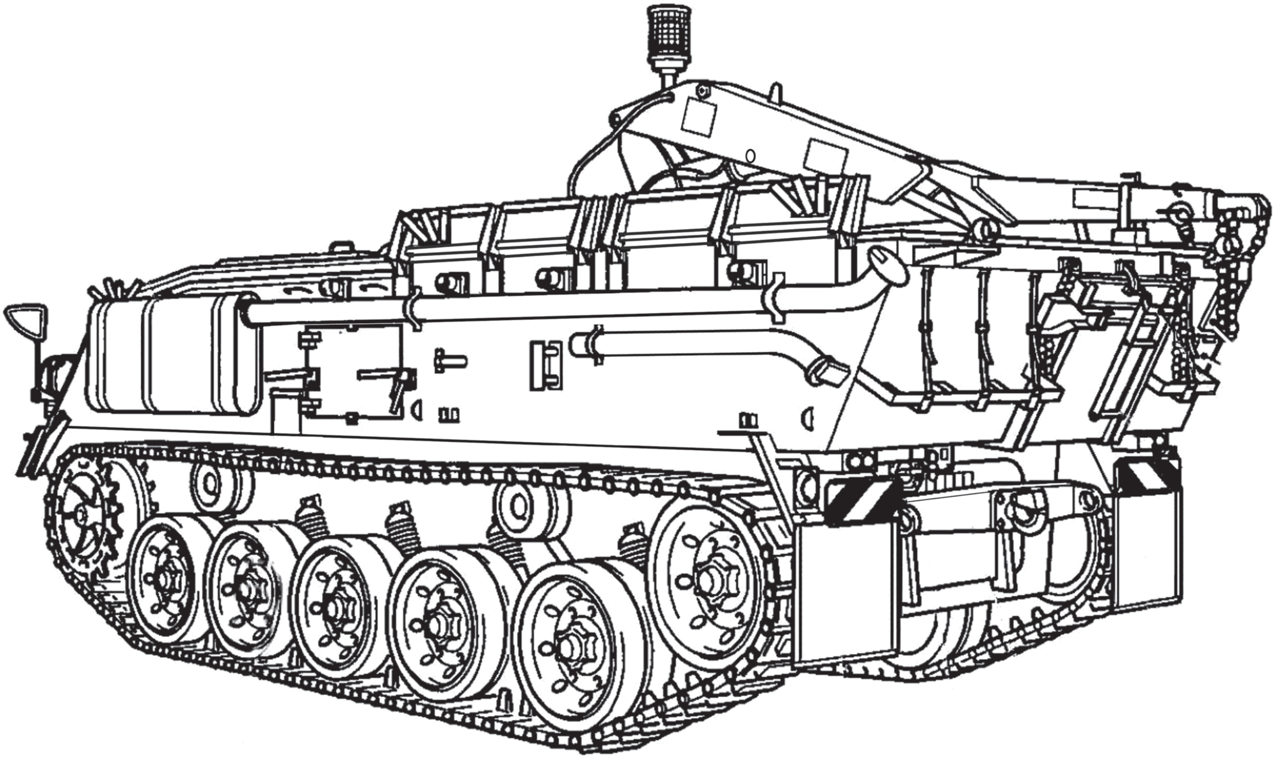
02SP65
SP 105mm
ABBOT



Abbot fitted with Falcon light anti-aircraft turret. (Crown Copyright MOD)

Regiments of the Royal Artillery in BAOR and by May 1967 it equipped six regiments. Abbot could fire High Explosive, HESH, Smoke, Illumination and Indicating rounds. Up to 40 rounds could be carried in the vehicle with the normal load being 32 HE and six HESH; the HESH providing an anti-tank capability in emergencies. The only other nation to purchase Abbot was India which fielded 80 vehicles, 68 of which were 'value-engineered versions'. These had a number of differences to reduce cost including deletion of the power traverse and rammer, smoke dischargers, swimming screen and infrared equipment, use of a simplified commander cupola and sight and reduced stowage.

One FV433 was modified by having its turret replaced by the Falcon Light Anti-Aircraft turret with twin 30mm Hispano-Suiza cannons, but this was a private venture modification by Vickers and never entered service. In September 1977 a report was issued covering a study into a lightweight self-propelled anti-aircraft system to supplement the man-portable Blowpipe focusing on FV430-series-based solutions. The Falcon turret and the GTS2 turret on an Abbot hull were considered along with the US Vulcan system mounted on an FV432, in a similar configuration to that in service with the US Army mounted on M113. The GTS2 turret had been developed by a French consortium consisting of GIAT, Thompson and Samm and mounted twin 20mm cannons. The study included a review of replacing the engine in order to enable the vehicle to keep pace with Warrior.



Drawing of FV434 REME repair vehicle. (Crown Copyright MOD)

Vickers did propose a 13-ton tank based on Abbot transmission and running gear. it was to be armed with the 76mm gun fitted to Saladin and two Vigilant anti-tank missiles but this proposal never progressed to the design stage.

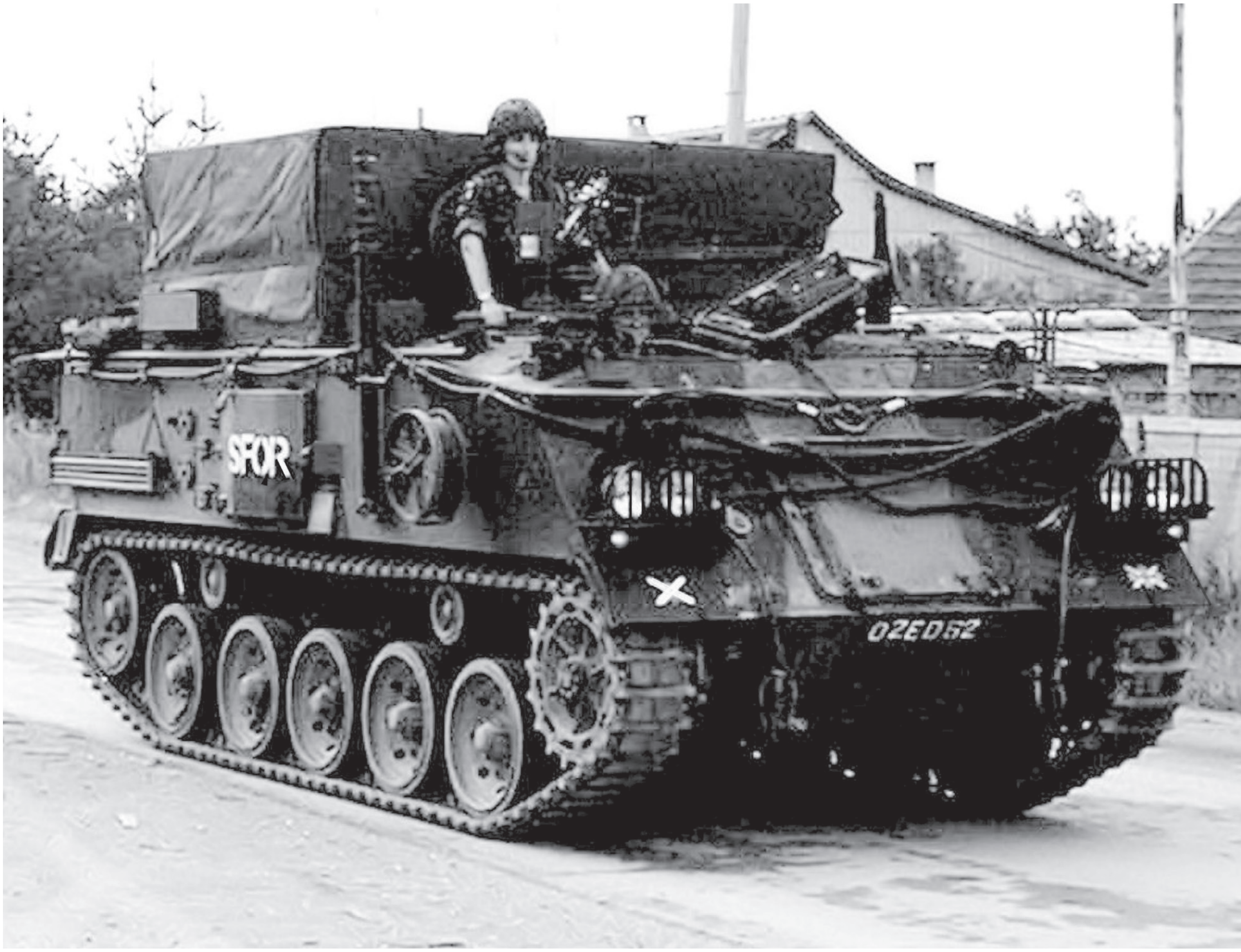
FV434

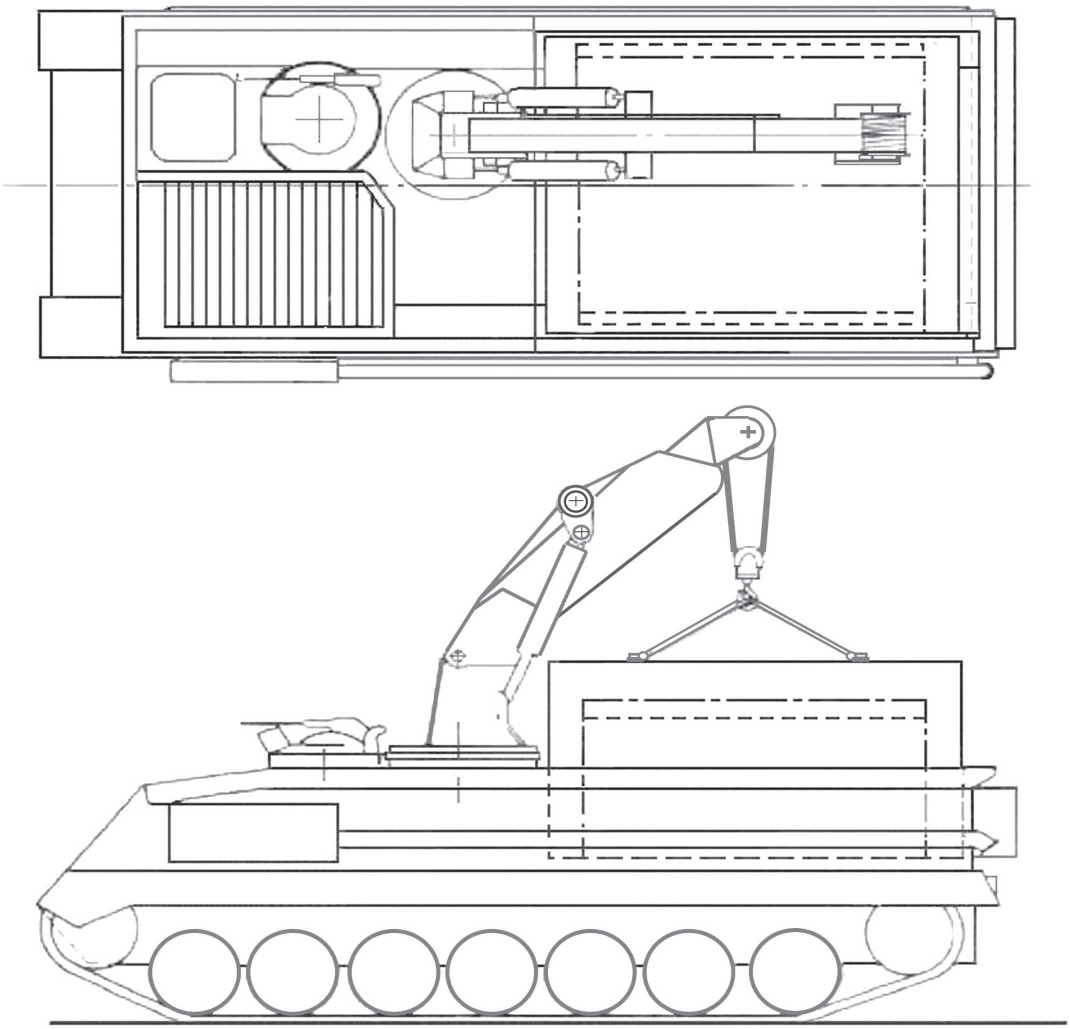
The FV434 was developed for REME with its primary role to repair disabled and damaged vehicles. As with FV432 the hull of the FV434 was manufactured using an all-welded steel construction. The crew of four consists of commander, driver (who is also the crane operator) and two fitters. The driver and commander are located in a tandem formation at the front left of the vehicle. An additional small hatch is provided in the roof of the small crew compartment. The driver uses the same AFV No.33 Mk 1 periscope as FV432 which can be replaced by an infrared periscope for night driving. The commander has a cupola with three No.32 Mk 1 periscopes for observation. Armament is either a 7.62mm L4A4 (Bren) light machine gun or a 7.62mm L7A2 GPMG.

To the rear of the commander's position is the load area which is normally protected by a tarpaulin cover. The running gear is the same as FV432 but the first and fifth road wheel stations are provided with hydraulic shock absorbers which are normally locked when the crane is in use. On the right side of the vehicle is a Hiab crane which can rotate over 90 degrees and has a lifting capacity of 3,050kg at 2.26 metres and 1,250kg at 3.96 metres; this was suitable for changing the power pack on Chieftain, however, it was inadequate for lifting the heavier Challenger power pack when that vehicle entered service.

As part of studies into requirements for a Forward Repair Vehicle (FRV) to support FMBT, consideration was given to a vehicle based on a 'stretched' FV432 chassis as a cheaper alternative to a vehicle based on the MICV that was then in its concept phase.

FV434 serving with the NATO SFOR (Stabilisation Force) in Bosnia. (Crown Copyright MOD)



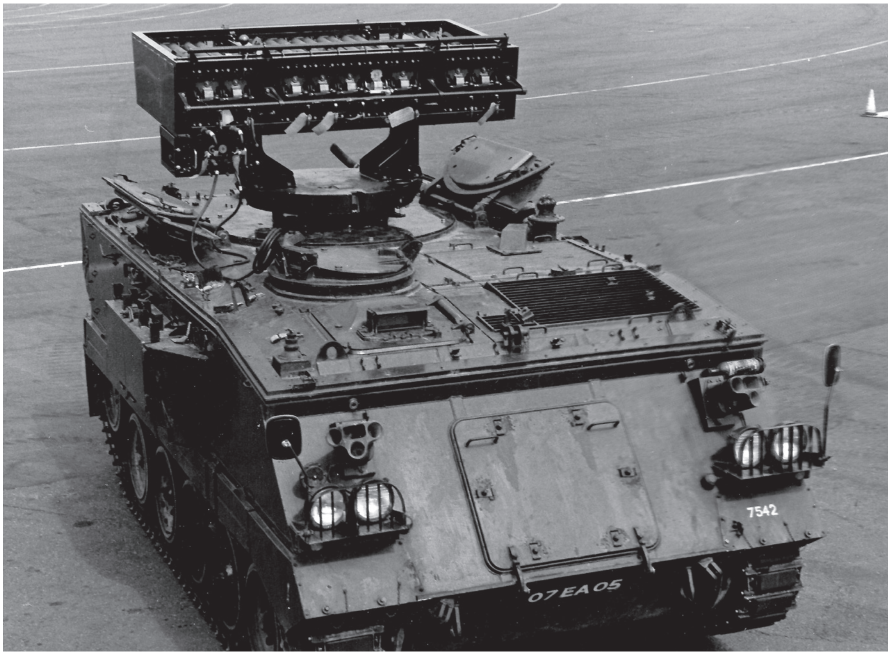


Concept for stretched 432 Forward Repair Vehicle. (Crown Copyright MOD)

The proposed vehicle had two extra wheel stations and the basic dimensions were:

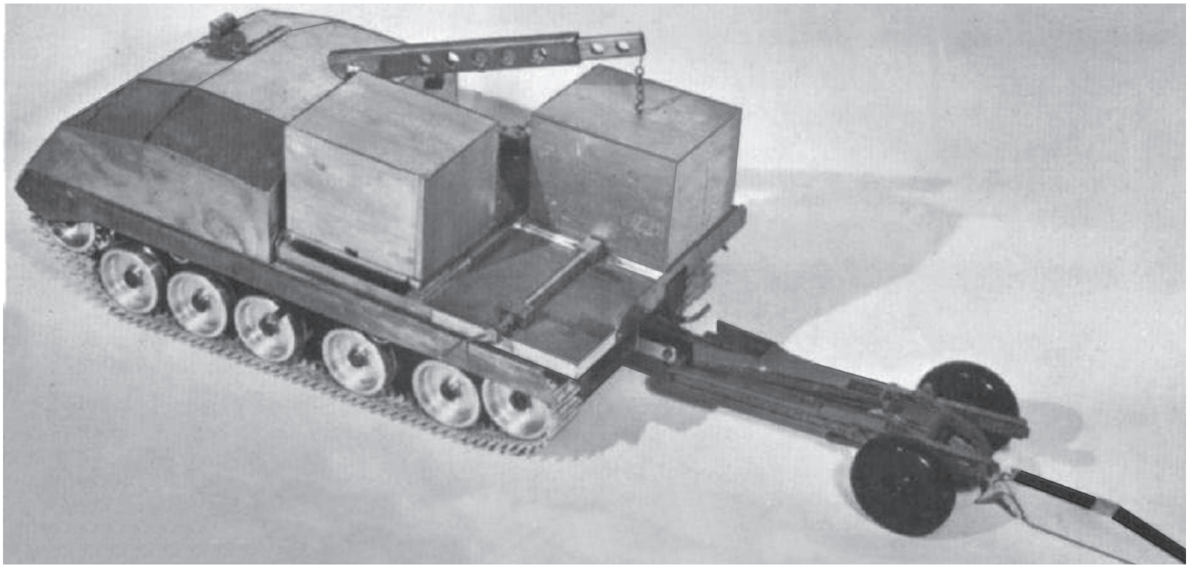
Length: 6,800mm
Width: 2,840mm
Height with crane in travel mode: 2,790mm

The estimated weight was 17.5 tonnes and a payload of up to 7.5 tonnes could be carried – with the FMBT power pack assumed to be 6.3 tonnes. The vehicle was to have a Rolls-Royce K60T engine rated at 280bhp driving through an improved TN15 gearbox.



FV432 fitted with Ranger Scatterable Mine Launcher. (Crown Copyright MOD)

Concept for FV435 Bar Mine Layer. (Crown Copyright MOD)



FV430 ENGINEER VARIANTS

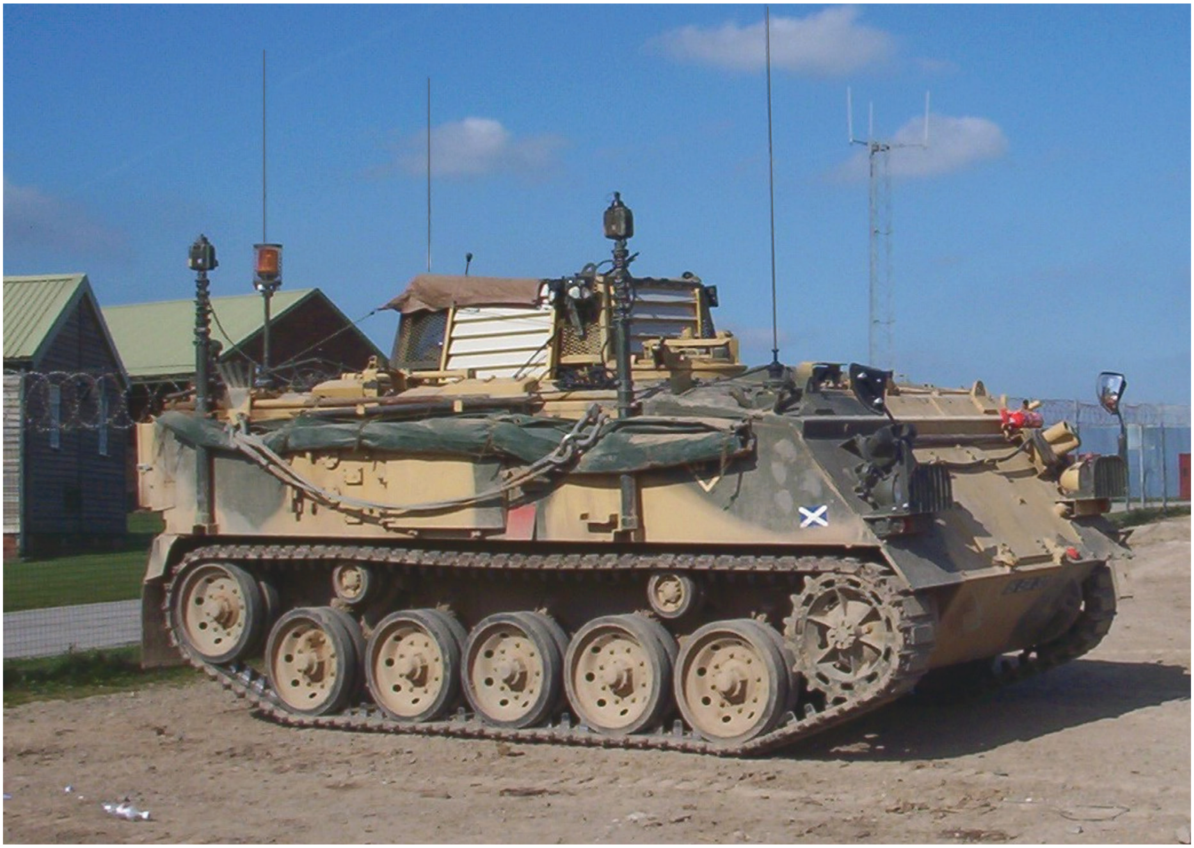
The FV435 designation had originally been assigned to a mine layer variant which was the subject of a design study which reported in April 1963. It was not taken forward and the mine-laying capability was eventually provided by a standard FV432 towing the bar mine layer which required the mines to be loaded by hand into the layer through the rear door aperture.

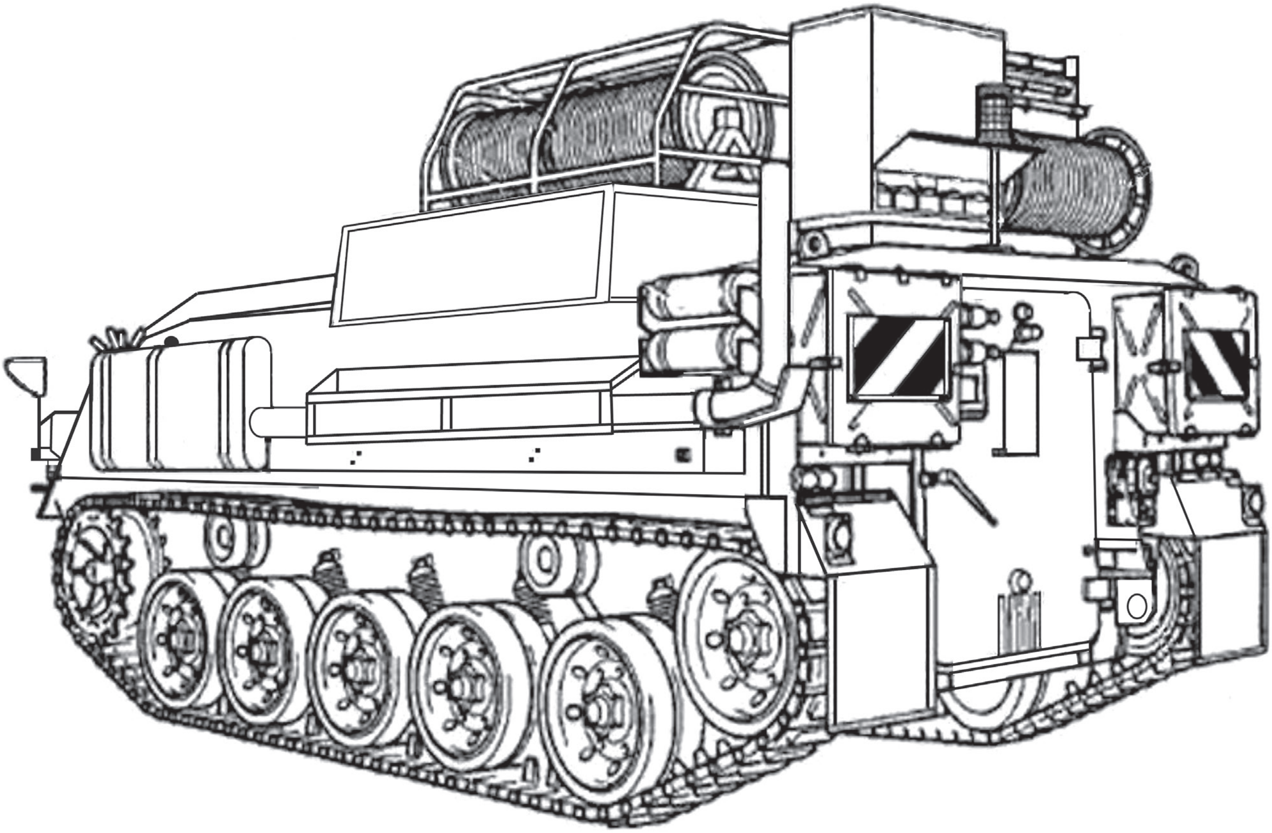
The Royal Engineers made use of the basic FV432 as a general purpose Royal Engineer (RE) vehicle for transporting stores and tools. In addition, a small number of FV432 vehicles were fitted with the Ranger Scatterable Mine Launching system. This was originally designed and tested in the early 1970s, but following testing at M a 'B Model' was developed which was simpler to use and maintain. This successfully completed trials in 1974. The ranger launcher mechanism could traverse over a full 360-degree azimuth and elevate to between 5 degrees and 35 degrees for firing.

FV430 SIGNALS VARIANTS

FV435 and FV439 were based on a standard FV432 hull but carried a wide variety of fittings and equipment associated with the command and

FV439 Signals vehicle. (Author's Collection)



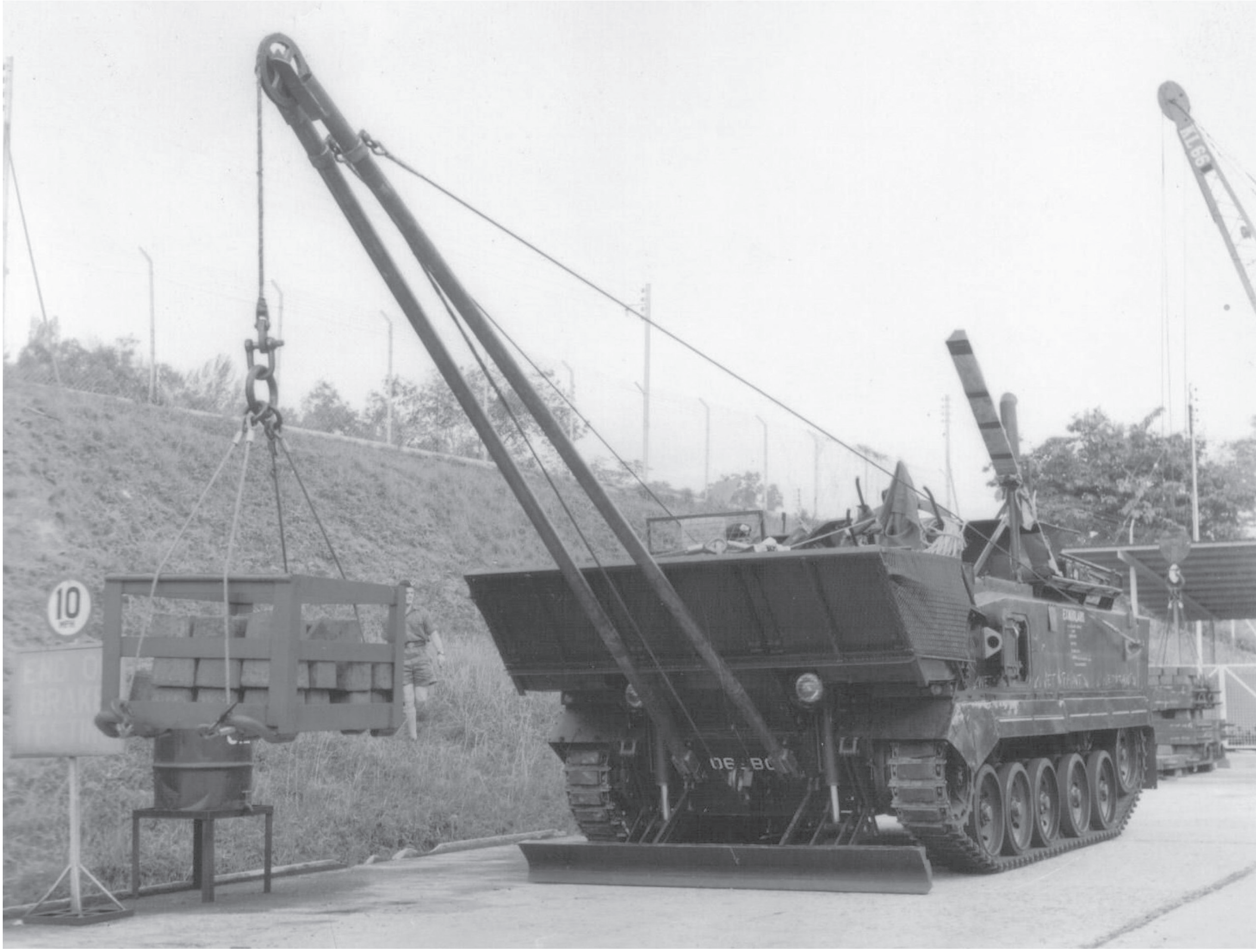


FV439 Radio Relay vehicle. (Crown Copyright MOD)

communications roles, including radio fits and communication masts. Versions included vehicles fitted with Wavell and Ptarmigan equipment. Some were fitted with air conditioning. There are two basic variants of FV439; a radio relay vehicle and a control vehicle (called the SAS/MC). Both variants have a generator mounted on the roof and the control vehicle has two additional batteries and the relay vehicle six. The relay vehicle has a mast-mounted radio antenna which can be extended to a height of 12 metres.

FV436

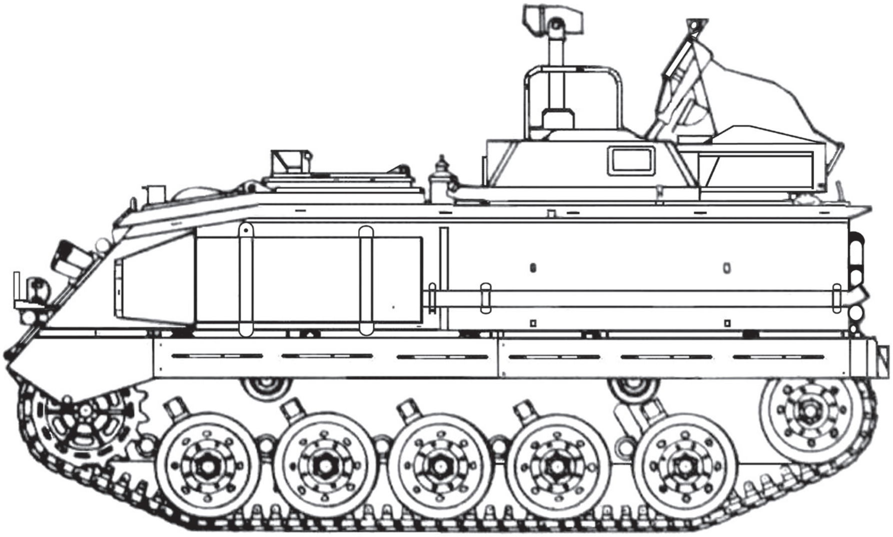
FV436 had a heavily modified hull, cut away at the rear, to carry the Radar FA No.8 'Green Archer' artillery locating radar system. Only one prototype was built and it did not enter service. Later the Cymbeline Radar was fitted to some FV432 platforms. Cymbeline was a mortar-locating radar designated 'Radar, Field Artillery, No 15'. The system



FV437 with deployed lifting jib. (Crown Copyright MOD)

fitted to FV432 was modified and designated the No.15 Mark 2. It was much smaller than Green Archer and was mounted on the roof of a standard vehicle with the operators inside. It undertook user trials with the Royal Artillery at Larkhill from March to May 1973 following which it was accepted for service use. Like FV346 the Cymbeline FV432 was operated by a crew of six.

The designation FV436 was later used for a command version called the Armoured Staff Vehicle (ASV). This was a basic FV432 with an extra generator and revised power distribution, office space for a staff officer and up to three operators working in the back and a Ptarmigan, later Bowman, secure radio fit.



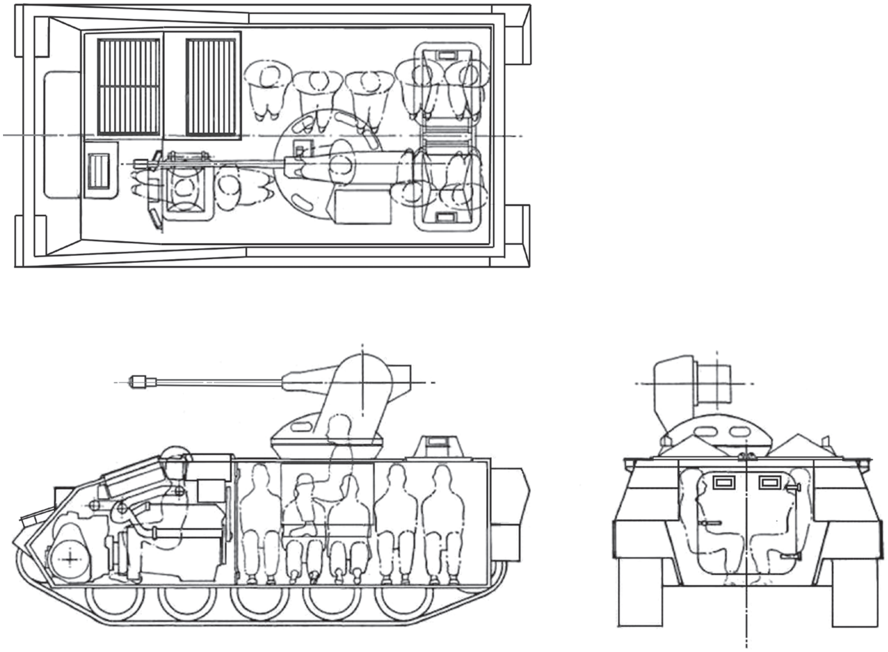
FV438 Swingfire launcher line drawing. (Crown Copyright MOD)

FV437 PATHFINDER

The FV437 Pathfinder vehicle was just over a ton lighter than FV432 and was designed to swim without preparation. The design and equipment exploited experience with FV420 which had also been designed to swim. It was also somewhat bigger than the FV432, especially with flotation aids, being 1,295mm longer, 50mm wider and 152mm higher. FV437 was sent to Thailand for Exercise Mudlark, a series of mobility trials in the jungle, where it took part along with Stalwart and some US vehicles. A useful feature of FV437 was its winch which performed well in the Mudlark trials both for recovering other vehicles and for self-recovery when bogged down. It was reported that without its winch none of the accompanying vehicles would have made it out of the jungle.

FV438 SWINGFIRE

The FV438 was the last variant to be fielded with production vehicles being available in 1968 and formal safety approval for full in-service use being issued in June 1969. This vehicle used the same basic FV432 hull but was fitted with twin Swingfire Long-Range Anti-Tank missile launcher tubes and associated sighting and guidance equipment. A total of 14 missiles could be carried and the launch tubes could be reloaded from under armour with a reload time of around 20–26 seconds per missile. It was later equipped with a thermal imaging sight and updated



MICV Light Concept with one person Oerlikon 25mm gun turret. (Crown Copyright MOD)

under the Swingfire Improved Guidance (SWIG) programme which provided a semi-automatic guidance system. FV438 was just over 900kg heavier than a standard FV432 and had a crew of three. It was fitted with an improved NBC filtration pack and a scheme was developed for an air curtain that enabled NBC protection to be maintained when the launcher was raised. FV438 has been withdrawn from service with the vehicles converted back to the standard FV432 configuration.

WARRIOR

Warrior Development

FV432 was a significant advance on the carriers it replaced, providing a fully enclosed and armoured crew compartment and NBC collective protection. It was, however, basically a 'battlefield taxi' rather than a fighting vehicle. The next evolution of the Armoured Personnel Carrier (APC) was as an Infantry Fighting Vehicle (IFV); this was driven by analysis that showed the benefits of not just using an APC for moving infantry around the battlefield but also providing it with an offensive firepower capability. Some initial work on potential IFV concepts began in early 1967 aimed at a replacement for FV432 around 1977/78 and in 1968 Chertsey presented an initial design that used a Fox turret, but included provision to fit an up-armoured Scimitar turret. These initial scoping studies went on to consider a number of concepts for what was then referred to as the Mechanised Infantry Combat Vehicle (MICV), covering MICV light at 14.6 tons, MICV medium at 24.2 tonnes, and a MICV with additional armour at 28.9 tonnes. In addition to meeting the needs of the British Army the stated requirements for the design were harmonized with very similar NATO requirements for an IFV. These were defined in NATO Specification A/C225(Panel II) D113. The initial MICV concepts formed the basis of other concepts covering a wide range of additional roles which were developed as part of the AFV for the 80s Phase 1 study; which is discussed below.

The MICV light concept used the same engine as the Combat Engineer Tractor (CET), then under development, linked to a TN6X gearbox. Suspension consisted of lightweight hydrogas units. Turreted and non-turreted variants were proposed. The internal volume was similar to that of FV432 and so it was recommended that the MICV light could be used as the basis for command and ambulance variants which did not warrant the greater expense of a vehicle based on the MICV medium concept; at that time MICV medium was projected to cost £55,000 and MICV light £43,000.

By the early 1970s the work at MVEE focused on more detailed design studies of the medium MICV for which there was now a firm requirement as the replacement for FV432. At that time two levels of armour protection were proposed with target weights of 22,400kg for the standard vehicle and 28,900kg for the up-armoured version. Following the MVEE scoping studies proposals were submitted by GKN and Vickers for the PD phase but these were considered technically inadequate; hence following endorsement of GSR 3533 for MICV in 1972 a PD Phase 1 was started ‘in house’ by Chertsey. This ran until 1976 with a number of initial designs being considered, the most advanced of which was a well-protected vehicle with Chobham armour and hydrogas suspension. The Chobham armour concept was rejected due to its higher weight (30 tonnes) and cost and a more conventional solution with an aluminium hull was selected as the preferred basis for full design and development. The design studies indicated that the driver’s compartment in MICV would need to be narrower than FV432 and studies into the use of a steering bar, rather than the traditional steering levers each side of the driver, had started. To test the human factors’ impact a FV432 was modified using panels to represent the more constrained driver’s space and a ‘steering bar’ integrated in place of the levers; this was used for trials in 1974. In 1976 studies were undertaken into a concept that used a space-frame construction which could be fitted with alternate armour packs. This was proposed so that the vehicle could be fielded initially with conventional armour, but this could be replaced by Chobham armour should the need arise. The concept also addressed the use of spall liners. A static demonstrator was built but the scheme was never adopted. It is of note that when Warrior, the vehicle eventually developed, was deployed in Kuwait, Bosnia, Iraq and Afghanistan it was fitted with extra armour to increase levels of protection. Thirty-five years later, under the Warrior Capability Sustainment Programme, there was a requirement for the vehicle to be provided with modular armour mounts to enable different appliqué armours to be more easily fitted.

With the more capable designs being dropped on the grounds of cost and weight the user requirements were revised and simplified. In addition, the in-service date was slipped to 1985. One aspect of performance that was not compromised was that of lethality. Chertsey staff carried out an assessment of the developing threat from Soviet vehicles and concluded that the 30mm RARDEN cannon system should be fitted. This was at the time when Germany had adopted a 20mm cannon for the Marder IFV and the US were to field a 25mm cannon on their Bradley IFV. At this stage in the programme it was envisaged that some vehicles would be fitted with a small turret with a GPMG turret rather than the larger and more expensive RARDEN turret. A review of the potential designs against the revised requirement led to the selection of what was called MVEE Concept MICV4A. Following this decision GSR 3533 was re-endorsed, reflecting revised and achievable requirements, and the in-service date postponed again to 1986. Following Ministerial approval a competitive tender process for full project definition was undertaken. This resulted in GKN being appointed as Prime Contractor in August 1977; the contract covered PD Phase 2, full development and the first production batch (Batch A). The resulting GKN solution, based on the MVEE MICV4 concept, was developed with ongoing support and guidance from the establishment. Based on the MVEE studies the design target was for a vehicle weighing 20 tonnes with a top speed of 75kph and a range of 500km. The suspension system was likely to be torsion bars, although hydrogas was still considered an option at that stage. The vehicle was required to carry a section of ten dismounts or seven in the anti-tank squad variant. The design was owned by the MOD allowing for a potential competition between manufacturers for future production contracts, although GKN had exploitation rights for overseas sales. A full-size mock-up was built and used for stowage and user trials at the ITDU at Warminster from July to August 1978. Meanwhile work on variants had started in January 1978.

On 1 January 1979 the project title was formally changed to Mechanised Combat Vehicle 1980 (MCV80) and by the end of that month GKN had submitted a PD Phase 2 report for the MCV80 IFV and the PD Phase 1 report for the variants. This led to approval for full development to start with a target date for user acceptance of November 1984.

Despite development being under way it had been decided that the US IFV under development at the same time should also be considered as an alternative to UK design. This was being developed by the FMC Corporation and would eventually go into service with the US Army as the M1 Bradley. Following a number of visits to the US a further contract was placed with GKN in October 1978 to carry out an assessment of a UK version of the vehicle, which was referred to as 'UK IFV'.

The UK IFV was envisaged as a simplified version of the US IFV without the integrated TOW ATGW and thermal imager. Further modifications were envisaged including relocation of the NBC pack and deletion of the hull-mounted periscopes for the dismounts in order to improve stowage. FMC built a mock-up of the UK IFV and between 3 and 17 December 1979 a UK team used it for stowage and initial human factors assessments at the FMC San Jose plant. Feedback was provided on potential design improvements covering areas such as driver cooling, turret crew space, seating and stowage locations. GKN issued a study report on the UK IFV in January 1979 at the same time as the PD Phase 2 report for MCV80. A further visit was made to the plant between 21 and 23 May 1980 to carry out an assessment of the integration of the weapon and ammunition stowage for a mortar variant.

However, by May 1980 the Defence Equipment Procurement Committee had decided that unless FMC could provide an improved contractual offer then the UK MCV80 solution would be adopted and the option to buy UK IFV dropped. An improved offer was not forthcoming and so on 14 July 1980 the Secretary of State for Defence formally announced that the UK MCV80 was to be procured rather than the UK IFV. Supporting this decision was an assessment of the two options which had concluded that although both vehicles could broadly meet the requirements of GSR 3533 the UK MCV80 design had a number of advantages, including:

Capacity: Both were comparable in terms of crew space but MCV80 had greater stowage capacity for the stores required for a 48-hour mission;

Mobility: MCV80 had a better power-to-weight ratio and a higher top speed on roads. The Perkins CV8 engine was rated at 550hp but had the stretch potential to run at up to 800hp;

Protection: The NBC collective protection, the ballistic and mine protection and battle damage limitation were all assessed to be superior for the MCV80;

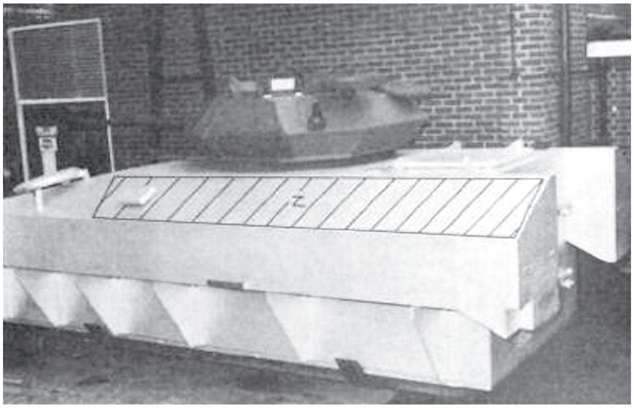
Firepower: The US version of the IFV was armed with TOW missiles, which were not planned to be fitted to the UK IFV. The IFV had a stabilized cannon, unlike MCV80, but MCV80 had a 30mm, rather than 25mm, weapon;

Flexibility: MCV80 was considered to have greater flexibility for a more extensive range of variants;

Cost: A direct comparison of costs was difficult, however, the UK IFV was assessed to be significantly more expensive than MCV80.

The programme was then subject to a further delay due to a general moratorium on MOD spending imposed by the Treasury. There was also a minor change in requirement with the Hughes chain gun being specified instead of a GPMG as the coaxial weapon in the turret. Furthermore, in November 1980 it was decided that the variant with the GPMG turret would be dropped with all infantry vehicles being fitted with the RARDEN turret. This made it possible to reduce the number of prototypes from 16 to 12 giving savings in development costs. The first three of these prototypes had already been completed in 1980 before the decision had been made to procure MCV80 rather than the US-designed UK IFV. All

Model of MVEE MCV80 Concept with CVR(T) type turret. (Crown Copyright MOD)



Mock-up of MICV4a Concept fitted with Fox turret and used for ergonomic trials by the Infantry Trials and Development Unit. (Crown Copyright MOD)

the prototypes had been delivered and were taking part in trials by early 1984. In addition to the main prototypes a suspension test rig was also manufactured and provided to MVEE for trials.

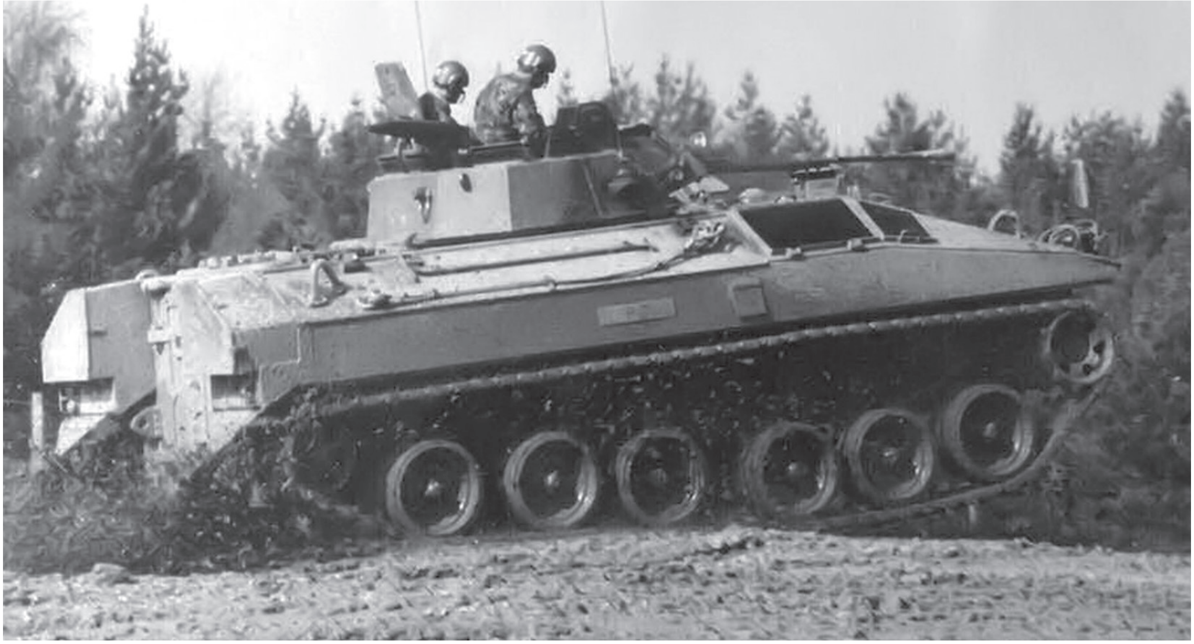
MCV80 had originally been intended as a full replacement for FV432 but, with the numbers reduced due to cost constraints, this was no longer the case. Therefore in 1983 a number of alternatives for making up the shortfall were considered, including an upgraded FV432, Stormer, the MCV80 GPMG turret version and APC90. APC90 was an MCV80 with one less wheel station and no turret. None of these went ahead although some upgrades to extend the life of FV432 were undertaken much later. In 1983 an 'Infantry Mobility Equipment Capability Policy Paper', which confirmed the ongoing requirement to field MCV80, was endorsed and the GSR 3533 was re-endorsed in October 1983.

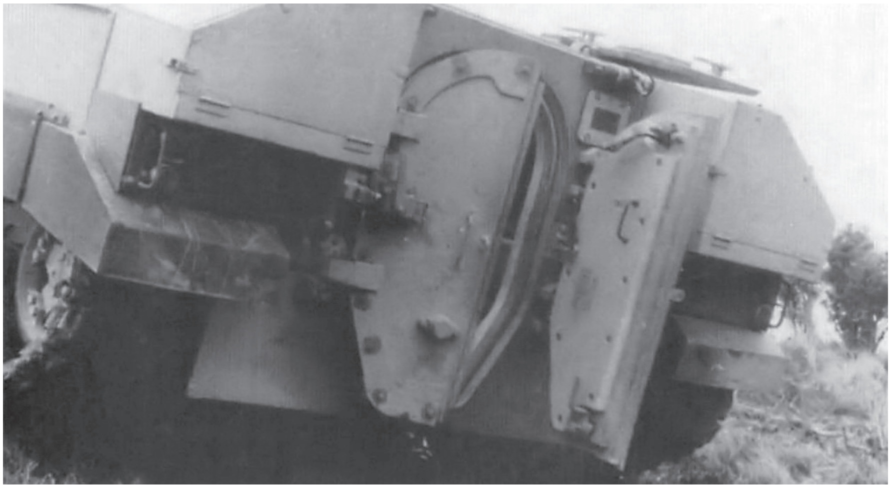
The Infantry Trials and Development Unit undertook user trials which ran from June 1983 until November 1984. Various prototypes were used at different stages with P6, P8, P9, P10 and P12 the ones used the most. A significant issue highlighted during the trials was the difficulty in opening the rear doors when the vehicle was parked on a downward-facing slope. The original prototypes had twin rear doors and various solutions were proposed and tested including redesigned lightweight doors. The solution finally adopted was to have a single power-operated door. Once these trials were under way the unusual decision was made to carry out Phase 2 User Trials. The logic behind the Phase 2 User Trials was that the capability enhancements provided by MCV80 were so significant compared with FV432 that it was important to fully investigate the tactical, logistic and training implications of the new vehicle. The Phase 2 User Trials were undertaken by 1st Battalion Irish Guards, with ITDU support, in BAOR between 20 August 1984 and 30 November 1984 and included use during Exercise Lionheart. One of the aims of MCV80 participation during Exercise Lionheart was to confirm its ability to keep pace with the Challenger tanks that had recently entered service. Five vehicles took part in the Phase 2 User Trials, P2, P8, P9, P10 and P12, although P2 did not have a cannon fitted. P8 remained with BAOR after the trials for testing in snow and ice.

Following satisfactory user trials the vehicle was accepted into service and given the name Warrior. The first production vehicle was handed over in May 1987 and the first Warrior-equipped battalion was operational in mid-1988. Further production batches were also competed with GKN winning the resulting contracts. A total of 789 were built for the British Army.

The basic Warrior platform was designed to deliver a section of eight armoured infantry into combat and provide fire support. Seven dismounts are carried in the rear of the vehicle with inward-facing seating along each side and these are normally joined by the commander when they dismount, leaving the driver and gunner to operate the vehicle. Access is via a large rear door which, as discussed, is powered to ensure it can be opened and closed safely on slopes. The hull is made of aluminium and provides all-round protection against heavy machine gun and artillery threats and against cannon threats over the frontal arc. The engine and gearbox are mounted at the front of the vehicle driving front sprockets and the driver is located to the left of the engine. A central turret has a crew of two, commander and gunner, and is equipped with the 30mm RARDEN and coaxial machine gun. The gunner sits on the left-hand side of the turret which he can traverse to aim the gun using a manual hand wheel which he turns with his left hand. It provides coarse and fine traverse. There is also a power traverse control above the manual hand wheel. Elevation is also controlled with a hand wheel which he operates with his right hand, which also has the fire switch. To the right of the traverse hand wheel the gunner has access to a weapon selection box which can switch between off, cannon and coax machine gun.

UK IFV mock-up at the FMC San Jose Plant. (Crown Copyright MOD)





ABOVE
Prototype MICV undergoing trials. (Crown Copyright MOD)

LEFT
MCV80 Prototype with twin rear doors. (Crown Copyright MOD)

The commander is located on the right side of the turret. He also has a power traverse control which can override the gunner.

A major upgrade to Warrior was the Battle Group Thermal Imager (BGTI) programme which involved replacing the gunner's and commander's sights with combined visual and thermal sights. The upgrade also included fitting of a laser rangefinder and navigation system. The BGTI programme coincided with the introduction of Bowman and so in 1998–99 a broader Product Improvement Programme (PIP) study was

Warrior on exercise on Salisbury Plain. (Crown Copyright MOD)

undertaken to ensure all upgrades were carried out in a coherent manner. This reviewed a number of potential environmental and survivability upgrades and recommended fitting an auxiliary power unit and upgrading the electrical system.

Warrior has been successfully used operationally, seeing action in Bosnia, Kuwait, Iraq and Afghanistan. In order to enhance its effectiveness on operations Warrior has been fitted with a wide range of 'Urgent Operational Requirement' fits including improved mine protection, different appliqué armour fits, electronic counter-measures, air conditioning and additional protection for sighting systems.

Around 2015 there were proposals to remove the turrets from surplus Warrior platforms and re-role them as 'Armoured Battlefield Support Vehicles' but this idea has not been taken forward at the time of writing.

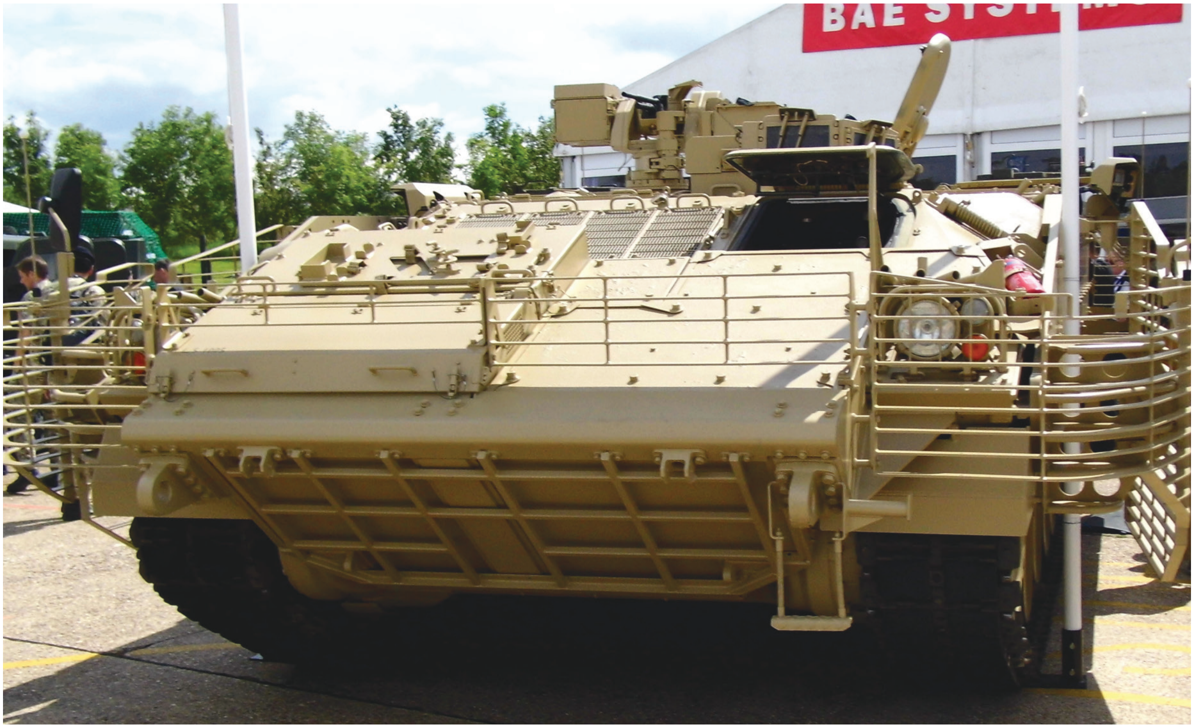
The in-service life of British Army Warriors was to be extended out to around 2040 under the Warrior Capability Sustainment Programme (CSP) the major component of which was a new turret with a stabilized 40mm cannon being fitted to a number of vehicles. The improved platform was designated FV520; however, in 2021 it was announced that the CSP programme was cut and Warrior would be taken out of service earlier with BOXER (discussed in a later section) intended as the main transport for armoured infantry.

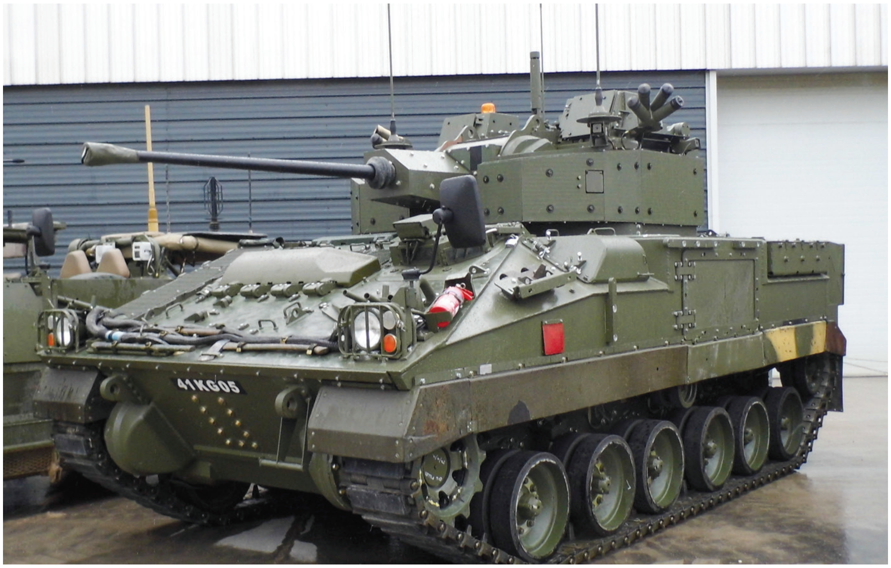
The only other user of Warrior is Kuwait which purchased 254 Desert Warrior vehicles. These vehicles had a number of design changes to ensure they were optimized for operation in desert conditions. It is fitted with a Delco turret mounting a stabilized M242 Bushmaster 25mm chain gun with coaxial 7.62mm chain gun and two Hughes TOW ATGM launchers (one mounted on each side). Warrior 2000 was developed against a specific Swiss Army requirement and had a more powerful engine, a Delco turret and modifications to reduce the radar and thermal signatures, but it did not enter production.

WARRIOR VARIANTS

As with other such platforms a number of variants were proposed and developed and the resulting family of vehicles is:

FV510: Infantry section vehicle
FV511: Infantry command vehicle





ABOVE
Warrior Armoured Battle-Group Support Vehicle with band tracks. (Author's Collection)

LEFT
Warrior Capability Sustainment Programme (CSP) with 40mm turret. (Author's Collection)

FV512: Repair vehicle
FV513: Recovery vehicle
FV514: Artillery observation post vehicle
FV515: Battery command vehicle.

The FV511 Infantry Command Vehicle is the same as the section vehicle apart from the provision of additional communication equipment.

The requirements for the other variants were defined in the GSR which evolved with each update. By 1983 requirements had been agreed for the:

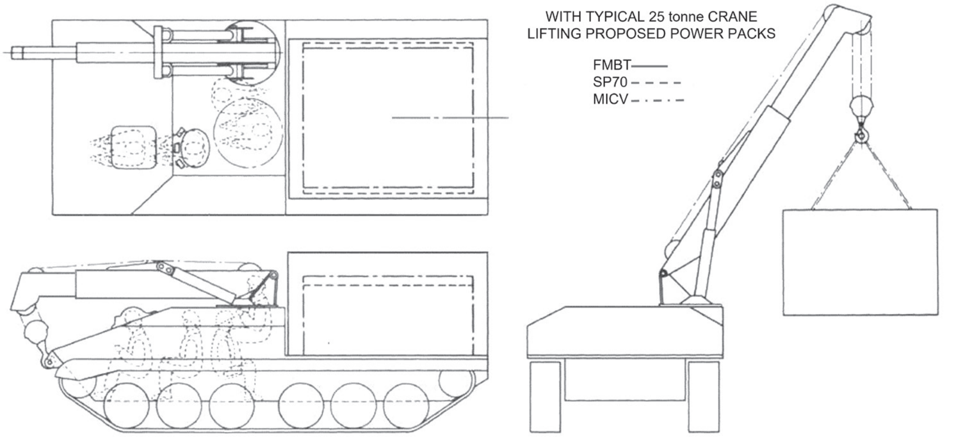
- Mechanised Combat Recovery Vehicle (MCRV) – to support MCV80 and Challenger;
- Mechanised Repair Vehicle (MRV);
- Mechanised Armoured Observation Vehicle (MAOV), covering both Battery Command (BC) and OP versions.

Recovery and repair variant requirements had initially been addressed in early concept work which had considered Recovery and Forward Repair Vehicle (FVR) variants which were based on stretched versions of the different MICV concepts.

The FRV concepts were designed to have the capability to lift and replace the power packs from FMBT, SP70 or MICV vehicles with the FMBT pack, at 6.3 tonnes being the heaviest. Basic data for the concepts shown was:

Concept four- based MICV FRV:

Length: 7,095mm
Width: 2,960mm
Height: 2,745mm (crane in travelling configuration)

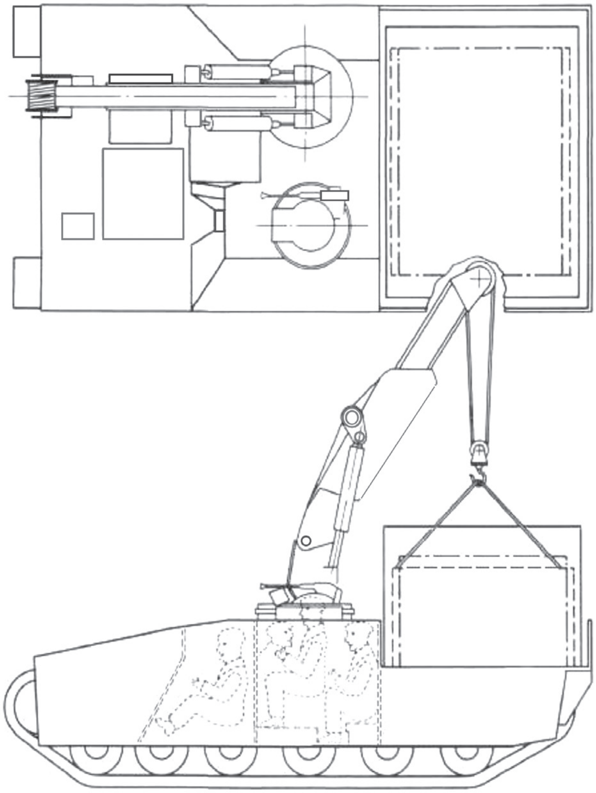


Forward Repair Vehicle based on MICV 4 concept. (Crown Copyright MOD)

Weight: 21.0 tonnes

Flat Top MICV FRV:

Length: 7,029mm
Width: 3,280mm
Height: 2,712mm (crane in travelling configuration)
Weight: 24.5 tonnes



Forward Repair Vehicle 'Flat Top' concept. (Crown Copyright MOD)

Both concepts had a 25-tonne crane and could carry a payload of up to 7.5 tonnes.

Following the concepts studies the repair and recovery variant requirements were eventually refined to be covered by two related platforms, FV512 Repair Vehicle and FV513 Repair and Recovery vehicle. FV513 was to be based on FV512 but with a winch added in the rear compartment of the hull and a full width earth anchor. A design requirement for these two vehicles was that they could be converted to either configuration by REME workshops should the need arise.

Although the initial feasibility studies into the repair and recovery variants were carried out as early as 1976, full development of the FV512 repair variant did not start until October 1984. Full development of the FV513 repair and recovery version started slightly later in March 1985. Development of FV512 ran to October 1987 with a User Acceptance report being issued on 7 December 1987 and the User Acceptance report for FV513 issued on 31 October 1988. Five prototype vehicles were built, three repair variants and two recovery variants. As well as the prototypes a complete hull for stress corrosion cracking trials and a 'crane test

Rear view of FV513 Warrior Recovery Vehicle. (Author's Collection) hull' were manufactured. In addition, an FV510 prototype, P6, was ballasted with an additional 3 tons to represent the increased weight of FV512 and was used for trailer-towing trials.

The FV512 and FV513 use a hull of the same configuration as the FV510 with the same engine and running gear but without the main turret. It has significant modifications to mount the special-to-role equipment and the vehicles are provided with 7.62mm chain gun for self-defence. FV513 is equipped with a 20-tonne Plumett winch and a pilot winch. It was heavier than FV512 at 30.99 tonnes, compared with 28.5 tonnes, and with a larger full width earth anchor it is 0.1m longer.

The production contract for the repair/recovery variants required 122 FV512 and 67 FV513 vehicles to be delivered by December 1994.

The FV515 Warrior Battery Command Vehicle (BCV) was developed for issue to Battery Commanders supporting Armoured Battlegroups and was manned by the commander and an additional four crew members. The hull and turret configuration is the same as the basic FV510 with the 30mm weapon and associated sighting systems retained. It was originally equipped with Battlefield Artillery Engagement System (BATES) and fitted with five radios, VRC353SZ (Regimental Net), two VRC353 to support BATES, PRC 351 for communication with the units it was supporting and a PRC 320 for use as a back-up. Additional special-to-role equipment includes an auxiliary power unit, a penthouse and air conditioning. User trials were carried out in January and February 1989 following which it was recommended for acceptance into service with 19 being fielded.

Development of the Warrior Observation Post Vehicle (OPV) (FV514) followed on slightly behind that of the BCV. It was developed as the main vehicle for Royal Artillery OP teams and carried specialist equipment to facilitate target acquisition and to provide target information, including range and bearing, for artillery weapon systems supporting the Battlegroup. It is equipped with communications system to support liaison with the Battlegroup HQ and the passage of target data to the supporting Royal Artillery units. Additional special-to-role equipment fitted to the OPV included the APES (Azimuth, Position and Elevation System) system and the MSTAR (Man-portable Surveillance and Target Acquisition Radar). In order to provide adequate space inside the vehicle for the additional equipment the 30mm cannon and associated ammunition stowage are not fitted; however, a dummy gun barrel ensures the vehicle looks very similar to a standard Warrior. The vehicle mounts a 7.62mm chain gun in the turret for self-defence purposes. Either the gunner or commander can traverse the turret with the commander having an override on the power traverse mode. The elevation handwheel and fire selection switch is positioned between the gunner and commander so that either can elevate and fire the weapon. It carries 2,200 rounds of ammunition. The BCV and OPV versions were designed to have as much commonality as possible to facilitate conversion between the roles if required.

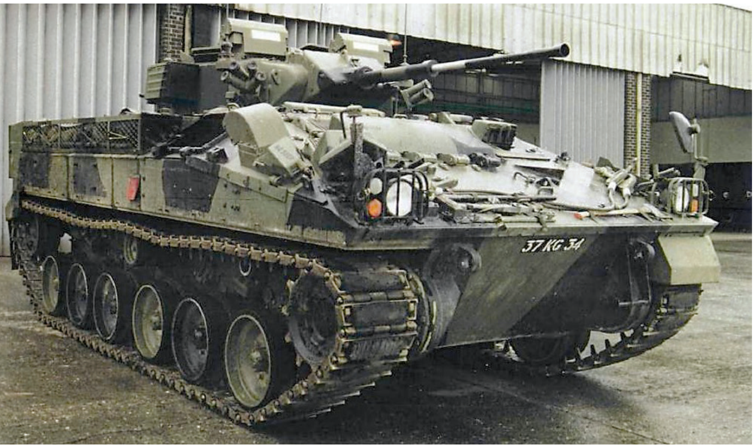
Some FV515 vehicles have been converted to an ambulance role with modifications including the removal of the weapons.

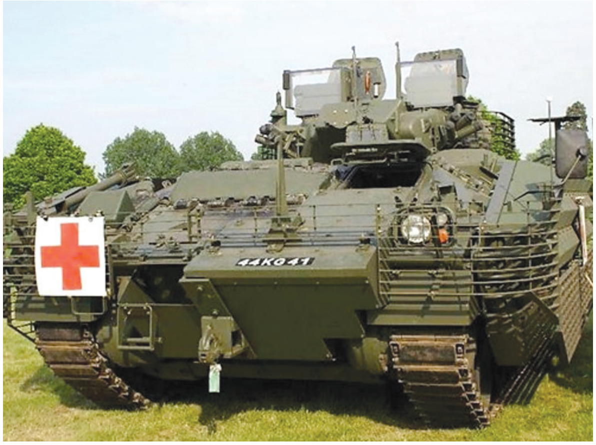
As Warrior was under development GKN proposed schemes for a number of variants including an APC with machine gun turret, 30 tonne tank with a 105mm gun, a recce vehicle with a turret mounting either a 75mm or 90mm gun, an ATGW variant using the Milan Compact turret, self-propelled anti-aircraft cannon vehicle, and an SP anti-aircraft missile variant. A Multi-Launch Rocket System (MLRS) launcher and MLRS resupply vehicle were also proposed later. GKN also generated a number of design proposals that were fed into the Future Light Armoured Vehicle study described in a later section. One private venture variant which did result in a demonstrator was an advanced reconnaissance version. This was a shorter vehicle with five road wheels with advanced features to reduce its thermal and radar signatures. It mounted a telescopic mast with thermal imagers and a surveillance radar.

Even when Warrior was still to enter service a study was undertaken into a version to carry and launch the Medium Range Trigat anti-tank

BELOW
FV515 Ambulance. (Crown Copyright MOD)

FAR LEFT
FV514 Observation Post Vehicle. (Crown Copyright MOD)





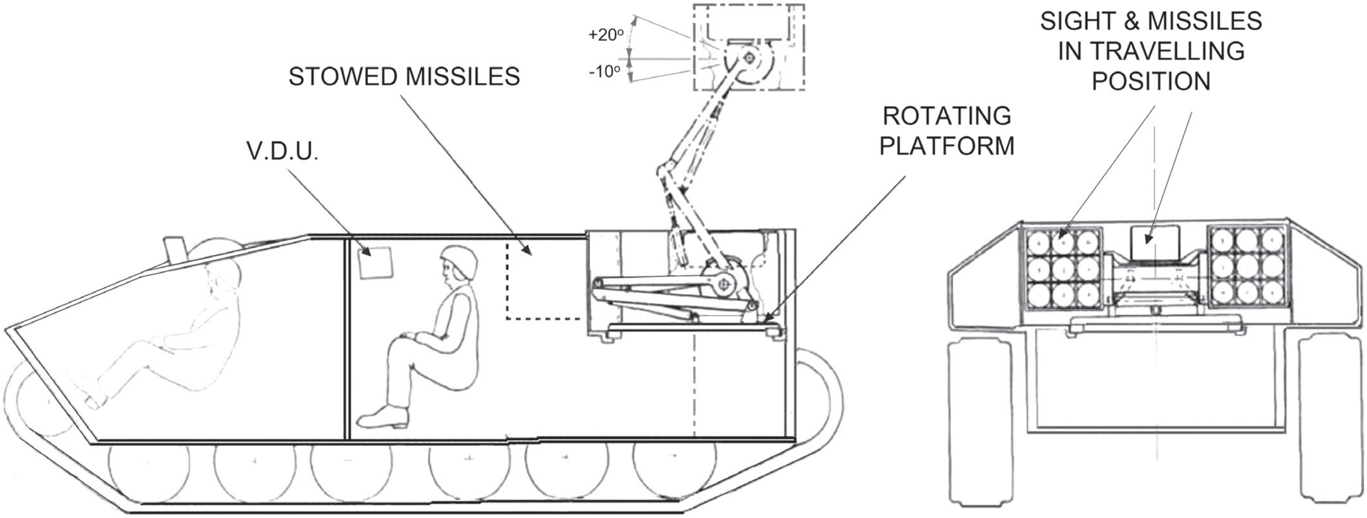
missile, then under development. The proposed concept had a crew of three and carried 36 missiles, 18 of which were ready to fire and carried in an elevating pod.

In February 1999 Chertsey issued a report on a concept study into potential solutions to replace Warrior around 2012. A range of concepts were proposed including:

1. A conventional evolutionary vehicle with either a manned or unmanned turret weighing between 19 tonnes and 22 tonnes.
2. A heavy IFV with high levels of armour protection and weighing up to 52 tonnes.
3. A small IFV, two of which would be required to carry a section of infantry, weighing 13.2 tonnes.
4. An articulated vehicle weighing 21 tonnes but capable of being fitted with additional armour up to a total weight of 40 tonnes. This concept envisaged the two halves of the vehicle being split to enable each half to be transported in a C130.
5. A Challenger-based 'Kangaroo'.

None of the concepts were developed further as by this time the focus was on light solutions to meet the Future Rapid Effects System (FRES) requirements.

Concept for MCV80 based MR Trigat ATGW vehicle. (Crown Copyright MOD)



AFV FOR THE 80S STAGE 1

As previously discussed, during the early stages of MICV development, a comprehensive review of requirements for the future Armoured Fighting Vehicle fleet was carried out as the 'AFVs for the 80s' project. Stage 1, which initially reported in 1969, addressed the requirements for medium-weight armoured vehicles with an emphasis on potential variants based on the MICV light and medium concepts then being developed. In addition, the hull of SP70, the joint UK/German 155mm self-propelled gun under development at that time, was considered for some roles, including as the basis for a bridge layer.

The Army proposed a family of vehicles which included:

- IFV with a 30mm RARDEN cannon in a crewed turret;
- IFV with a 25mm Oerlikon external cannon (as an alternative to the turreted RARDEN);
- Swingfire anti-tank guided weapon launcher;
- Self-propelled mortar;
- Self-propelled 155mm artillery system;
- Self-propelled rocket launcher with the FOIL rocket;
- Self-propelled Rapier anti-aircraft system.

The foil rocket system was a ground-to-ground rocket for which initial concepts were developed to meet GST3427. The missile was 2.9m long, 178mm diameter and weighed 159kg. High-explosive, fragmentation and cluster bomb warheads were proposed. Chertsey carried out a comprehensive study into different platforms for a self-propelled launcher and, as well as the MICV-based version, versions based on CVR(T), Chieftain, and wheeled vehicles were proposed as well as towed versions. The MICV-based version carried eight rockets.

In addition, as part of the study, concepts for a medium-weight Main Battle Tank were developed for comparison with the heavy MBT concepts that were developed in Stage 2. Other intended variants included Command, Ambulance, Weapon Locating Radar (Zenda), recovery and engineer variants, however, concepts for these were not developed as part of the study.

The use of the cheaper MICV light, discussed above, was proposed for some roles such as Command, Ambulance and GW launcher.

Although it was still intended to field CVR(T) as part of the AFV for the 80s fleet mix it was recognized that the MICV light would be better for some of the roles due to its larger capacity; for example CVR(T) was considered too small for the Zenda Radar system.

To explore solutions to meet the requirements, a number of concept designs were developed based on the proposed MICV medium, including:

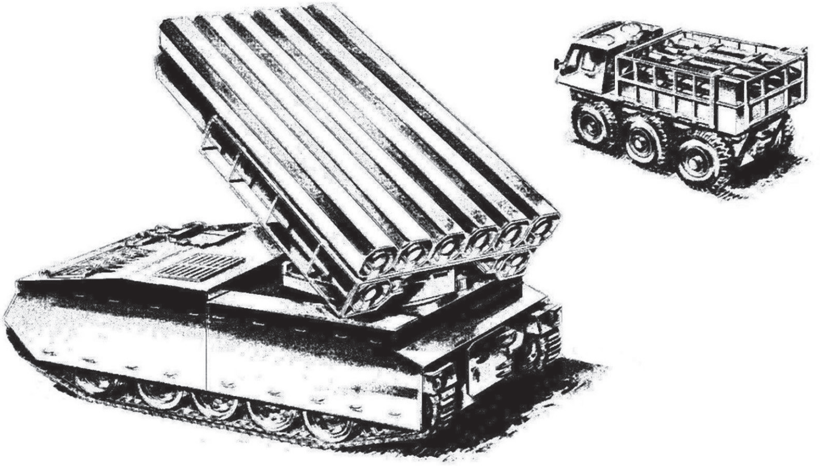
- Turreted versions:
  - Basic vehicle with Fox turret
  - Basic vehicle with Scimitar turret
  - Up-armoured version with Scimitar turret
  - Basic vehicle with Oerlikon 25mm external gun
  - Up-armoured version with Oerlikon 25mm external gun
- Non-turreted versions:
  - APC, suitable for other roles
  - Up-armoured APC
  - Mortar variant
  - Up-armoured mortar variant

Schemes for turreted variants that could also carry a mortar were also developed. One unusual idea considered for some concepts was the 'reversible turret roof'. This had a large circular aperture towards one end which could be used as the mounting for the turret ring or for mortar hatches. Two smaller side-by-side apertures towards the other end could be used for mounting a cupola or a small GPMG turret. In use as a turreted vehicle the large aperture was towards the front of the vehicle and in use as a mortar vehicle the roof was turned round with the large aperture towards the rear.

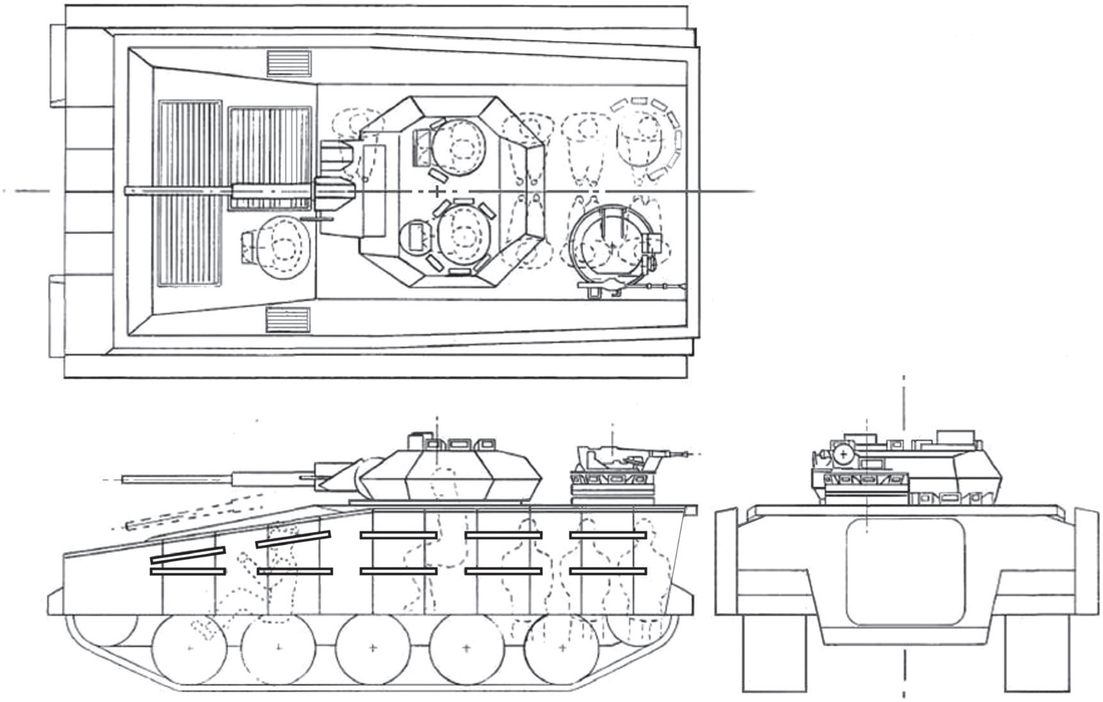
The main characteristics of the turreted versions were:

- Basic vehicle with Fox turret: length 6,220mm, width 3,250mm, height 2,380mm, weight 21,800kg;
- Basic vehicle with Scimitar turret: length 6,210mm, width 3,160mm, height 2,500mm, weight 22,400kg;
- Up-armoured vehicle with Scimitar turret: length 6,210mm, width 3,600mm, height 2,500mm, weight 28,900kg.

The requirement for the SP 155mm artillery system was complicated by the fact that the UK was already working with Germany on the SP70



MICV based rocket launcher concept. (Crown Copyright MOD)



Reversible roof plate MICV concept. (Crown Copyright MOD)

155mm system. It was clear that SP70 would be significantly heavier than variants in a medium-weight fleet, hence the interest in an MICV-based solution. The resulting concept was based on MICV components but had torsion bar suspension and an extra wheel station to carry the additional weight compared with the IFV versions.

The MICV-based MBT activity exploited previous studies into the '25-ton tank concept' and COMRES 75. Initial schemes were developed for a vehicle with an external gun on a front engine configuration hull to provide commonality with the IFV variant. Such a layout enabled the ammunition to be stowed in the rear of the hull for ease of loading. The high levels of armour protection considered necessary for an MBT were not viable with a front engine configuration and so rear engine concepts were then developed. The concepts generated were:

- External gun concept with a 110mm high-velocity (HV) main armament;
- External gun concept with a 110mm HV main armament and 30mm coaxial cannon;
- External gun concept with smaller medium-velocity main armament;
- Conventional turreted concept;
- Self-propelled anti-tank gun with limited traverse gun.

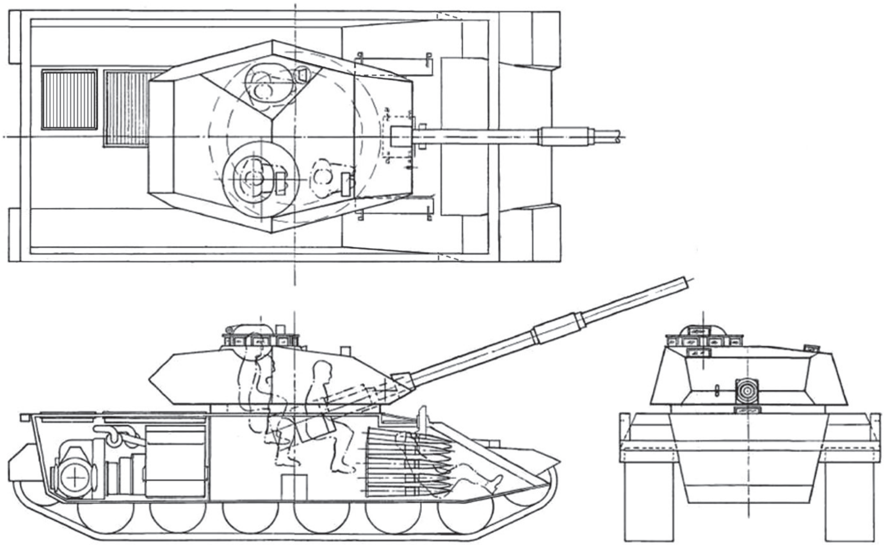
All the concept MBTs used MICV running gear but had an extra wheel station to carry the additional weight, which was up to 35 tonnes.

The manned turret concept had a 1,800mm turret race ring, which was the smallest feasible for a three-man turret crew. The vehicle weighed 32.21 tonnes but was only armoured against 30mm APDS threats. The self-propelled anti-tank gun concept had +/-10-degree traverse and solutions with two different levels of armour protection were developed, the heaviest at 36 tonnes.

In order to support the AFV for the 80s study, full-scale mock-ups were built of MICV medium, MICV light and the Medium Tank concepts.

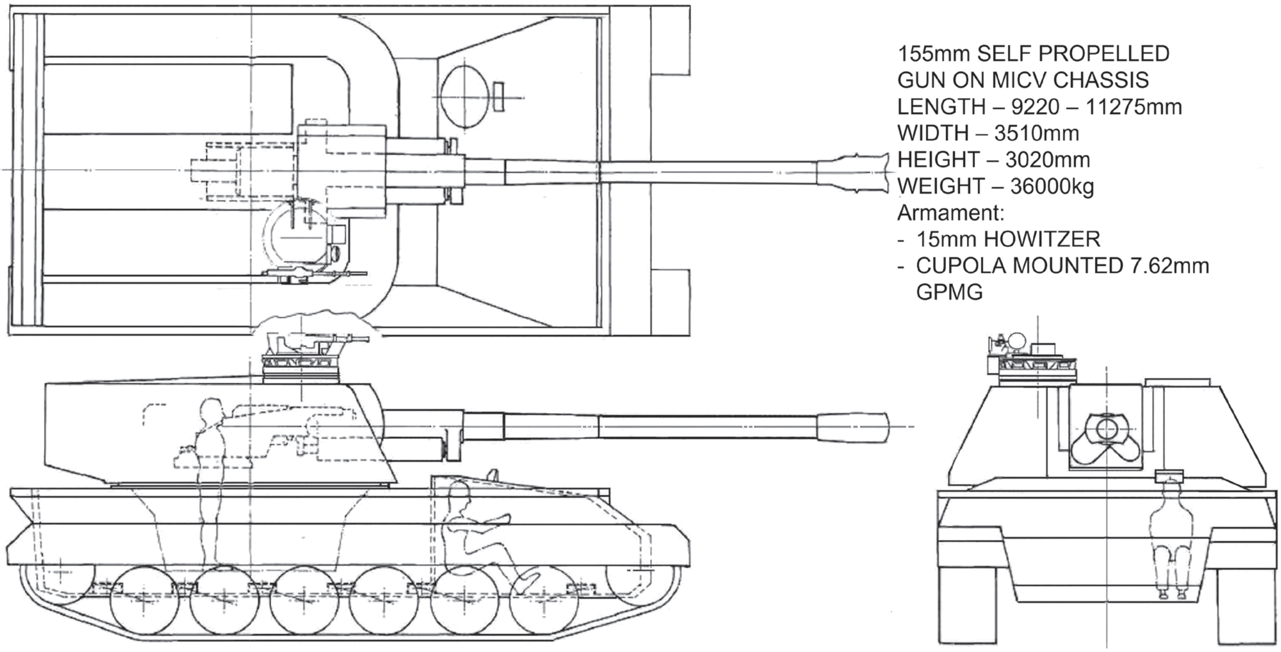
AFV FOR THE 80S STAGE 3

Stage 3, which reported in January 1973, addressed a requirement for a medium-weight MICV-based SPAT and the CVR(T)-based Air-Portable Self-Propelled Anti-Tank (ASPAT) described in a previous section. The requirement for the SPAT was raised in an Army Department Paper OR42/71 dated 30 July 1971. It called for a smaller and lower-cost vehicle compared to the turreted tanks which it was intended to support. The aim was to be at least 20 per cent cheaper than an MBT. Versions with a three-man crew or a two-man crew plus an autoloader were considered although



LEFT
MICV based medium tank concept. (Crown Copyright MOD)

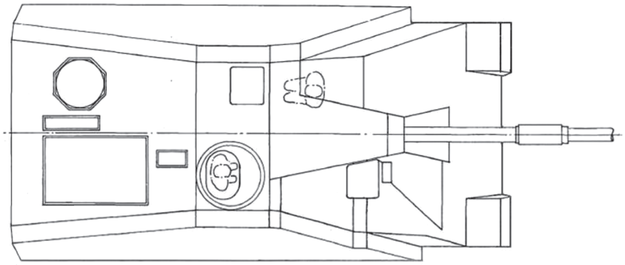
BELOW
MICV based 155mm self-propelled gun. (Crown Copyright MOD)



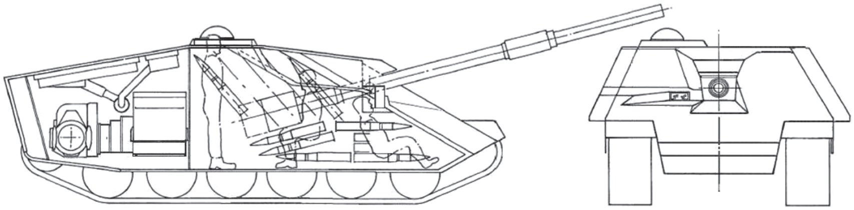
155mm SELF PROPELLED
GUN ON MICV CHASSIS
LENGTH – 9220 – 11275mm
WIDTH – 3510mm
HEIGHT – 3020mm
WEIGHT – 36000kg
Armament:
- 15mm HOWITZER
- CUPOLA MOUNTED 7.62mm GPMG

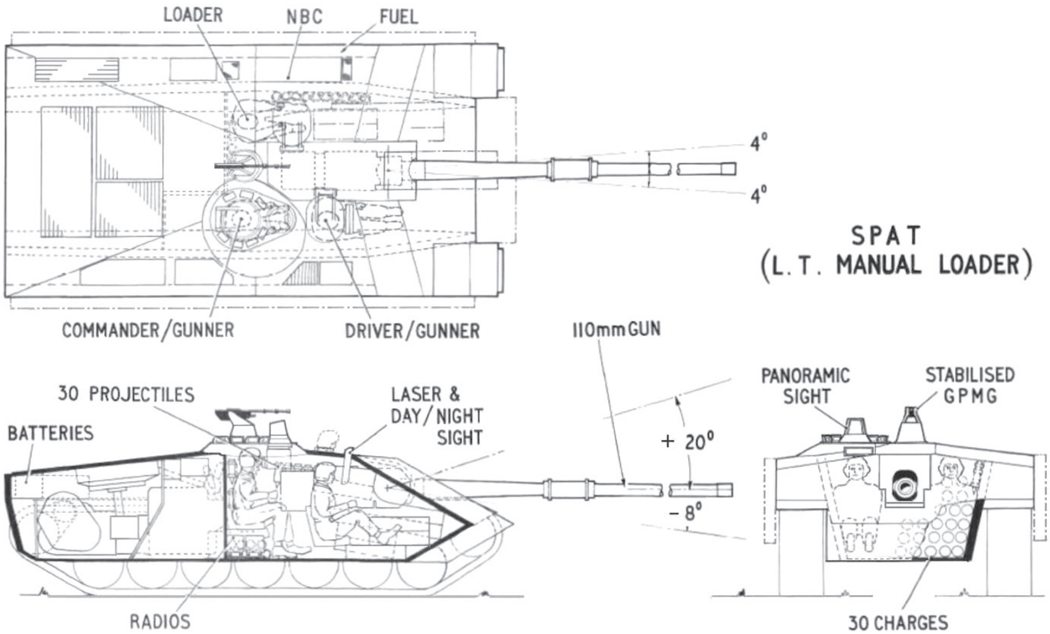
the final presented concepts had a three-man crew. Two weapon-aiming concepts were considered; Semi-Fixed (SF) where the gun could elevate but azimuth aiming was achieved by turning the whole vehicle and Limited Traverse (LT) where following course aiming by turning the whole vehicle fine laying could be achieved by exploiting a limited (+/-4 degrees) weapon traverse. The semi-fixed was recommended due to the complexities of gun and fire control solutions for the limited traverse.

RIGHT
MICV based fixed gun tank concept with additional armour. (Crown Copyright MOD)

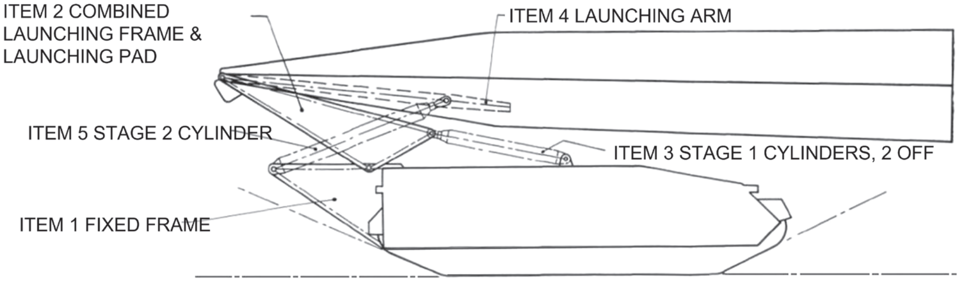


BELOW
Self-propelled anti-tank with limited traverse main armament. (Crown Copyright MOD)




LOADER
NBC
FUEL
4°
4°
SPAT
(L.T. MANUAL LOADER)
COMMANDER/GUNNER
DRIVER/GUNNER
110mm GUN
30 PROJECTILES
BATTERIES
LASER &
DAY/NIGHT
SIGHT
+ 20°
- 8°
PANORAMIC
SIGHT
STABILISED
GPMG
RADIOS
30 CHARGES

RIGHT
Initial scheme for a MICV based bridge layer – rear launch version. (Crown Copyright MOD)


ITEM 2 COMBINED
LAUNCHING FRAME &
LAUNCHING PAD
ITEM 4 LAUNCHING ARM
ITEM 5 STAGE 2 CYLINDER
ITEM 3 STAGE 1 CYLINDERS, 2 OFF
ITEM 1 FIXED FRAME

The basic data for the MICV-based SPAT was:

Dimensions: SF: length hull 6,591mm, length overall 9,855mm, width 3,505mm, height 2,438mm
LT: length hull 6,591mm, length overall 10,020mm, width 3,505mm, height 2,438mm
Engine: CV8 at 750hp or CV12 at 800hp
Maximum speed: 62kph
Suspension: seven road wheels per side with hydrogas units
Weapon: 110mm
Weapon aiming: Elevation -8 to +20 degrees; azimuth fixed or +/-4 degrees
Stowed rounds: 30
Protection: over frontal arc: MBT protection levels (with Chobham armour)
Protection: over sides and rear: MICV levels
Mass: 42 tonnes for SF concept, 43-tonne LT concept

The likely small numbers that the British Army would require, only around 300, meant it was assessed that the vehicle would not be cost-effective and so was not taken further.

A supporting study to the AFV for the 80s project was undertaken by the Military Engineering Experimental Establishment at Christchurch covering bridging variants. This study considered bridge layers based on MICV light, derivatives of five- and six-wheel station versions or MICV and SP70 with weights ranging from 12 tons for the MICV light bridge layer, 34 tons for the heaviest MICV variant and 35 tons for the SP70 variant. The available payload for the bridge and launch mechanism was considered marginal for all the concepts based on an unmodified MICV hull and so the report proposed a modified variant of a six-wheel MICV concept with heavy torsion bar suspension. A range of launch mechanisms were considered including scissors, fixed span, folding ramp and telescopic; with the scissors mechanism being recommended as the most practical. An issue with the MICV concepts was mounting the launch mechanism at the front of a front-engined vehicle and so rear launch concepts were considered.

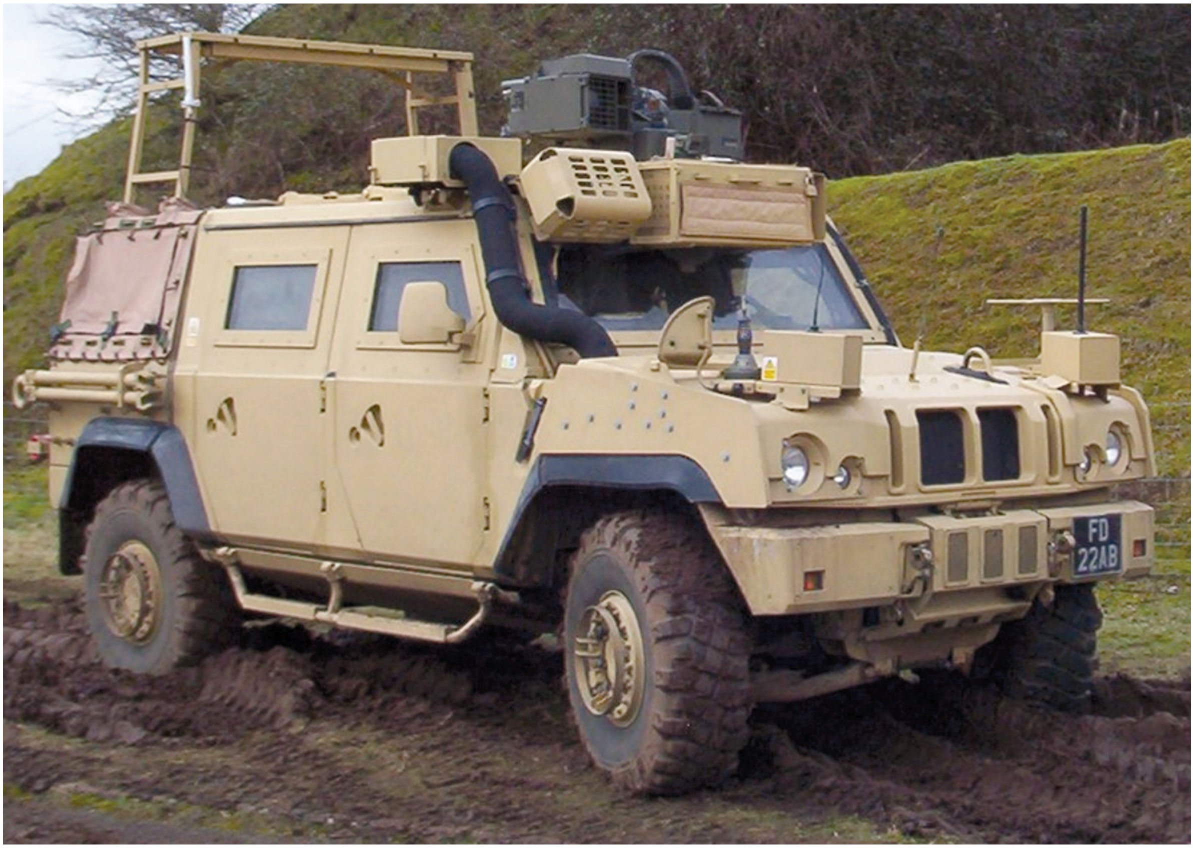
OTHER LIGHT AND MEDIUM TRACKS CONCEPT STUDIES

Following transfer of design authority to industry in 1982 Chertsey continued to undertake work to generate and validate vehicle requirements and to assess products and designs proposed by industry. This work was often supported by the generation of high-level concepts for medium and light AFVs, based on 'the art of the possible'. The concept designs enabled realistic performance data to be generated for use in computer 'war games' and to act as a baseline for assessing proposals from industry.

In the mid-1980s Chertsey supported a wide-ranging study into the potential shape of the light and medium AFV fleet from 1990 onwards; this was called the Family of Light Armoured Vehicles (FLAV) study. The study aimed to define a coherent approach to replacing a wide range of in-service platforms including CVR(T), FV432, M548, CET, Fox, Ferret, Saxon and Saracen, along with some 4-tonne trucks and Land Rovers used in forward areas. The scope of the study potentially covered the replacement of 2,900 tracked vehicles and 3,700 wheeled vehicles. Included in the assessment were vehicles to cover a wide range of roles including an IFV with a medium-calibre gun, self-propelled artillery, anti-tank guided weapon platform, mortar, air defence, rocket launcher, scatterable mine dispenser, tank destroyer, signals, repair, recovery, engineer, cargo, ambulance and internal security. The requirements set defined a number of classes of vehicle covering different weights, mobility levels and protection levels.

Analysis of requirements led to a recommendation that a fleet of six classes of vehicles was required. The vehicles fell into two classes of mobility, M1 for tracked vehicles and M2 for wheeled vehicles. In addition, three levels of protection were considered with P1 as enhanced protection, P2 as basic protection and P3 as a minimum level of protection for vehicles unlikely to operate in forward areas of the battlefield. In broad terms an M1/P1 vehicle would be at least as good as Warrior in terms of mobility and protection and M2/P2 required the vehicle would be no worse than Saxon.

The six classes of vehicle are shown in Table 7.



Panther Command and Liaison Vehicle. (Author's Collection)

Table 7: **Classes of Vehicle Proposed for the Family of Light Armoured Vehicles**

	Running Gear	Weight Class	Mobility	Protection	Engine
FLAV 1	Tracked	8–14 tonne	M1	P1/P2	250bhp
FLAV 2	Tracked	14–20 tonne	M1	P1/P2	350bhp
FLAV 3	Tracked	20–30 tonne	M1	P1	550bhp
FLAV 4	Wheeled	3–8 tonne	M2	P2/P3	180bhp
FLAV 5	Wheeled	8–12 tonne	M2	P2	250bhp
FLAV 6	Wheeled	12–24 tonne	M2	P2	250bhp

A comprehensive review was carried out of in-service platforms against the requirements along with a high-level review of foreign platforms within the required weight classes and proposals from UK industry. UK industry was tasked to propose families of existing or new vehicles to meet the requirements. Four proposals were received which were then assessed by the Chertsey team against the mobility and protection requirements. The proposals were:

1. GKN Ltd:
    - Warrior (M1, P1) LOVATT; a vehicle based on Warrior components but with a lower hull (M1, P1/P2)
    - Saxon; the in-service 4x4 troop carrier (M2, P2)
    - Simba; a 4x4 wheeled vehicle offered as an improved alternative to Saxon (M2, P2)
    - Satan; a 6x6 wheeled utility vehicle (>M1, P2).
2. Alvis:
    - CVR(T) (>M1, P2)
    - Stormer (M1, >P2)
    - Ferret 80; an improved Ferret with an aluminium hull (M2, P2).
3. Royal Ordnance:
    - RO 2000; a family of new tracked vehicles including an APC (18 tonnes), 120mm mortar carrier (18 tonnes), 122mm self-propelled artillery system (20 tonnes) and an anti-tank vehicle mounting a 105mm gun with autoloader (21.5 tonnes) (M1, P2)
    - Pandur; a 6x6 wheeled vehicle built by Steyr-Daimler-Puch (>M2, P2).
4. Vickers Defence Systems:
    - Mark 5 Light Tank; 20-tonne tracked vehicle with a 105mm gun (M1, P1)
    - NVH1 MICV; a 17-tonne IFV of Chinese design with either a RARDEN turret or an Oerlikon 25mm cannon turret (<M1, P3)
    - Valkyr; a 4x4 troop carrier (>M2, P3)
    - Vedette; a 6x6 vehicle developed as a private venture to meet an Australian requirement (>M2, >P2).

A full report summarizing the assessment of candidate platform was issued in 1986.

Based on the findings of the Chertsey study in November 1988 the Operational Requirements Branch in MoD generated what was called the ‘Future Family of Light Armoured Vehicle (FFLAV) Philosophy Paper’. This reiterated the need to replace ageing platforms such as

Ferret, which had been in service for over 40 years, and FV432 and CVR(T). In addition, it noted the need for improved mobility for platforms to keep up with Challenger and Warrior, the need for improved protection and the requirement for armoured vehicles to replace Land Rovers and trucks in some roles. The paper called for a higher degree of commonality across the fleet to support more efficient logistics and training. The full scope of FFLAV roles covered:

- Long and Medium Range Trigat carriers/launchers (Trigat was a European Anti-Tank Guided Missile project);
- Mortar;
- Armoured Reconnaissance;
- APC (for roles covered by FV432, Spartan, Saxon, Saracen and lorries);
- Command, Control and Communications vehicles;
- Artillery Forward Observation Officer;
- Ambulance;
- Commander transport/rover (role covered by FV432, CVR(T) and Land Rover);
- Liaison (role covered by Ferret and Land Rover);
- Repair and Recovery;
- Mobility and Counter-mobility (roles covered by CET);
- RAF Regiment;
- Ptarmigan communications (transported by soft-skin lorries).

The scope of roles was slightly wider than that covered by FLAV and included new requirements for Trigat and reconnaissance vehicles. A Cardinal Points Specification (CPS) was drawn up to define the basic requirements of the fleet of vehicles with requirements for protection and mobility modified from those for FLAV. A higher level of protection, called P+, was defined along with three levels of mobility:

M1: High-mobility combat vehicle
M2: Good mobility vehicle
M3: Vehicle requiring limited cross-country mobility

The paper called for work to be carried out in three phases, with Phase 1 in two parts:

Phase 1a: Review by Chertsey of current vehicles against the CPS.
Phase 1b: Studies by the UK platform design authorities into the ability of their vehicles to meet the CPS requirements both with and without modifications.
Phase 2: Invitation for proposals from overseas suppliers.
Phase 3: Overall study and recommendations based on phases 1 and 2 (Carried out by Chertsey).

The object of the studies was to inform a procurement programme starting in January 1991. Whilst the studies were still under way the fall of the Berlin Wall occurred in 1989; this put all decisions on hold pending the 1990 Defence Review which led to a reduction in the defence budget. In addition, the Conventional Forces Europe treaty of November 1990 impacted on the allowable armoured vehicle inventory.

Although the changing political and financial situation meant that FFLAV would not go ahead as planned, Operation *Granby*, the liberation of Kuwait, with its build-up in 1990 and invasion in 1991 once again highlighted the inadequacy of some of the ageing platforms.

As a result of the changes and the recommendations from Chertsey following the FFLAV studies the Army Plans and Resources Committee endorsed a Light Armoured Vehicle Strategy Paper in May 1992. This noted that the FFLAV proposals from industry 'lacked innovation' but made the following recommendations for a fleet of vehicles based on the Chertsey study:

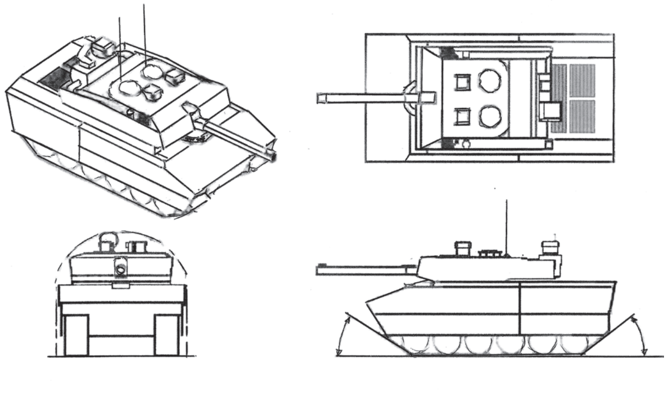
- Warrior, which was in production, would be a core vehicle and a future Mid-Life Improvement Programme would provide the enhanced P+ protection and have improvements to maintain M1 mobility;
- Saxon, which was in production, would continue to be fielded;
- A new reconnaissance vehicle with P1 protection and M1 mobility would be fielded;
- A new utility platform with P2 protection and M2 mobility would be fielded.
- A new liaison vehicle with P2 protection and M3 mobility would be fielded.

Remaining FV432, CVR(T), Ferret, Saladin and Saracen vehicles would be eventually phased out of service. Thus, the results of the FFLAV studies and the Strategy Paper eventually resulted in three programmes to address the three new platform requirements; these were:

1. TRACER reconnaissance vehicle.
2. Multi-Purpose Base Armoured Vehicle (MBAV) programme which started as a NATO project but evolved into the multinational Multi-Role Armoured Vehicle (MRAV) programme.
3. Future Command and Liaison Vehicle (FCLV) which resulted in the procurement of Panther which is a lightly armoured 4x4 utility vehicle with a comprehensive command and communications fit.

TRACER (Tracked Reconnaissance Armoured Capability Equipment Requirement) was a joint UK/US programme to develop a reconnaissance vehicle to replace CVR(T). The US programme was called the Future Scout and Cavalry System (FSCS) or 'Scout' for short. In order to support requirements Chertsey defined three Vehicle Concepts (VC) which were reported on in March 1992; these were:

- VC1: Evolution of CVR(T) with a front engine and a 40mm cannon;
- VC2: Rear engine vehicle without a turret and armed with long-range anti-tank missiles. Basic data: weight 19.5 tonnes, length 5.53m, width 2.53m, height to turret roof 1.95m, height overall 2.49m;
- VC3: Front engine vehicle with 40mm cannon and long-range anti-tank missiles. Basic data: weight 22.6 tonnes, length 5.78m, width 2.91m, height to turret roof 2.26mm, height overall 2.60m.



UK TRACER reconnaissance Vehicle Concept 3. (Crown Copyright MOD)

In addition, the analysis programme included US concepts covering upgraded versions of the Bradley M3 and the Scout Platoon M1114 HMMWV – the platforms FSCS was intended to replace – a STRYKER-based solution and ten wheeled and tracked new-build designs; both of which were intended to be light enough and small enough to be flown in a C130 Hercules.

A Staff Target for TRACER (ST 4061) was endorsed in mid-1992 and a programme of modelling and analysis started at Chertsey. The overall plan for the TRACER/Scout project was:

- Government studies and analysis 1992–95;
- Industry feasibility studies 1993–94;
- System definition studies 1995–96;
- Project definition studies 1997–99;
- Full development 2000–05;
- In-service 2006

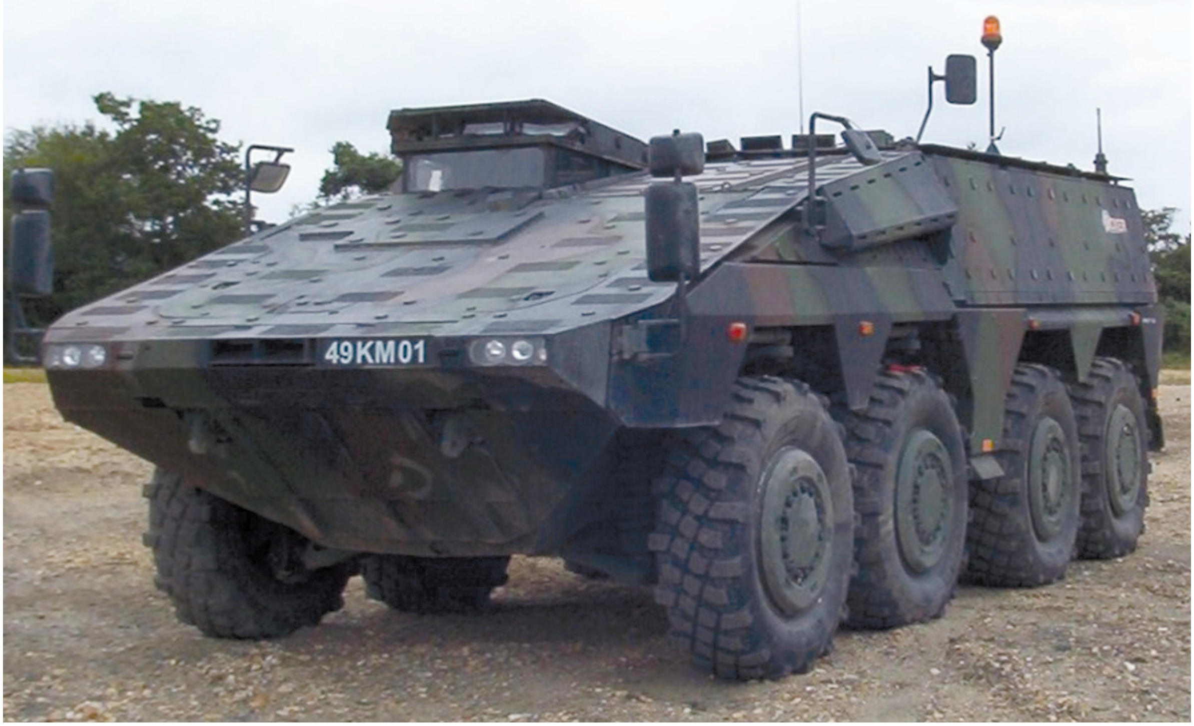
Two joint UK/US consortia, called SIKA International (British Aerospace, Lockheed Martin, Vickers Defence and General Dynamics) and LANCER (Marconi, Alvis, United Defence and Raytheon) were set up to carry out the industrial design and risk reduction studies and they both built demonstrator platforms as part of the PD activities to highlight key technologies and design features. Despite good progress the TRACER/Scout programme ended when the US withdrew and the project formally ended in October 2001.

One concept demonstrator that was intended to inform the TRACER programme was the Advanced Composite Armoured Vehicle Programme (ACAVP) which utilized a fully high-grade fibreglass composite hull as a means of reducing weight. The vehicle was based on Warrior running gear and mounted a Fox turret for demonstration purposes. ACAVP is now at the Bovington Tank Museum.

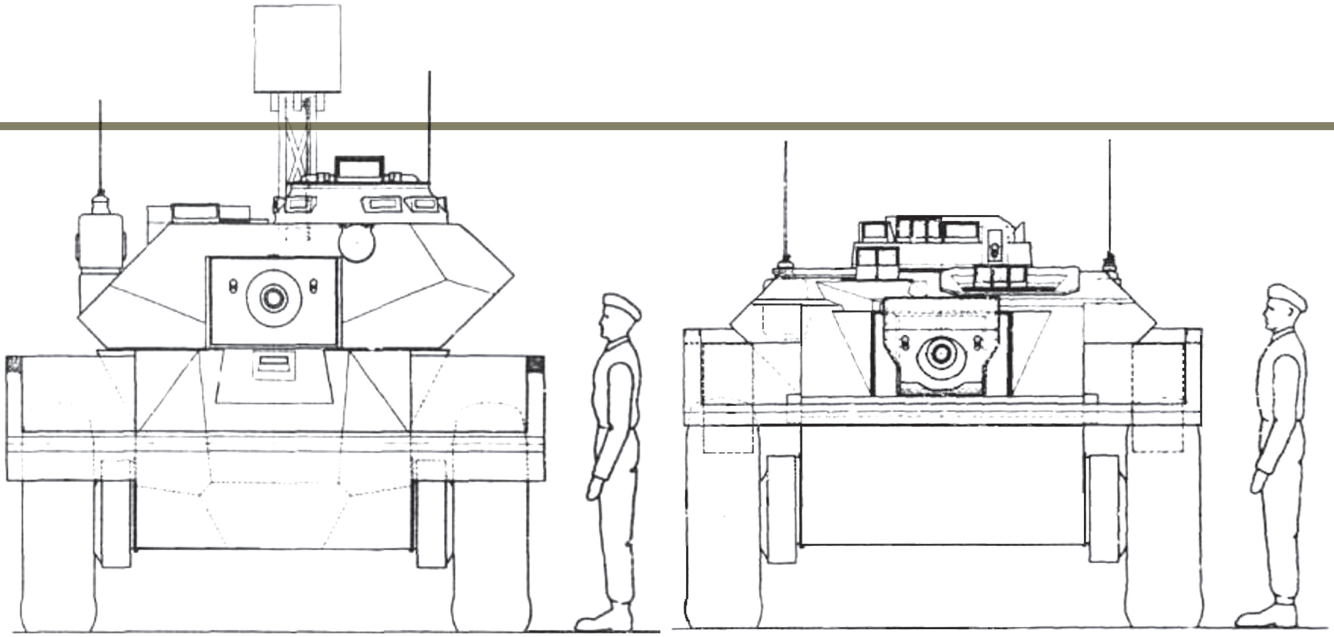
MRAV was intended, in part, as a replacement for FV432. In April 1997 Chertsey presented concepts for a national development programme covering both wheeled and tracked versions. The tracked version was based on Warrior components but had improved armour protection, a reduced signature, an improved ride through the use of hydrogas suspension, and the engine and transmission uprated to 650hp. It had a basic weight of 24.4 tonnes but was designed to be fitted with additional armour giving a battle weight of 33.3 tonnes. The wheeled vehicle was an 8x8 but with improved protection and a reduced signature compared with available platforms. The basic weight was 26.1 tons but designed to be fitted with additional armour bringing the weight up to 33 tons. It was then decided to join a joint programme with Germany and the Netherlands to jointly develop a vehicle which was eventually fielded by those nations as 'BOXER'.

Following the withdrawal of the US from the TRACER programme there was a further evolution of the requirements for future light and medium armoured vehicles for the British Army leading to the FRES programme. Despite being heavily involved in the design of BOXER, through the involvement of Alvis, it was decided that the vehicle was too heavy to fit within the FRES concept and the UK withdrew from that programme. The FRES project was split into two strands, Utility Vehicles (UV) and Specialist Vehicles (SV) which at the time of writing is intended to be met by the AJAX family of vehicles.

In 2021 developments came full circle with the decision to procure BOXER for the British Army with the vehicle to be manufactured in the UK by Rheinmetall BAE Systems Ltd (RBSL) who are based at Telford where the original GKN team who helped design MRAV/BOXER were based.



BOXER currently being procured to meet the British Army Mechanised Infantry Vehicle (MIV) requirement. (Author's Collection)



ABOVE
AVR Scheme A (left) and Scheme B (right).
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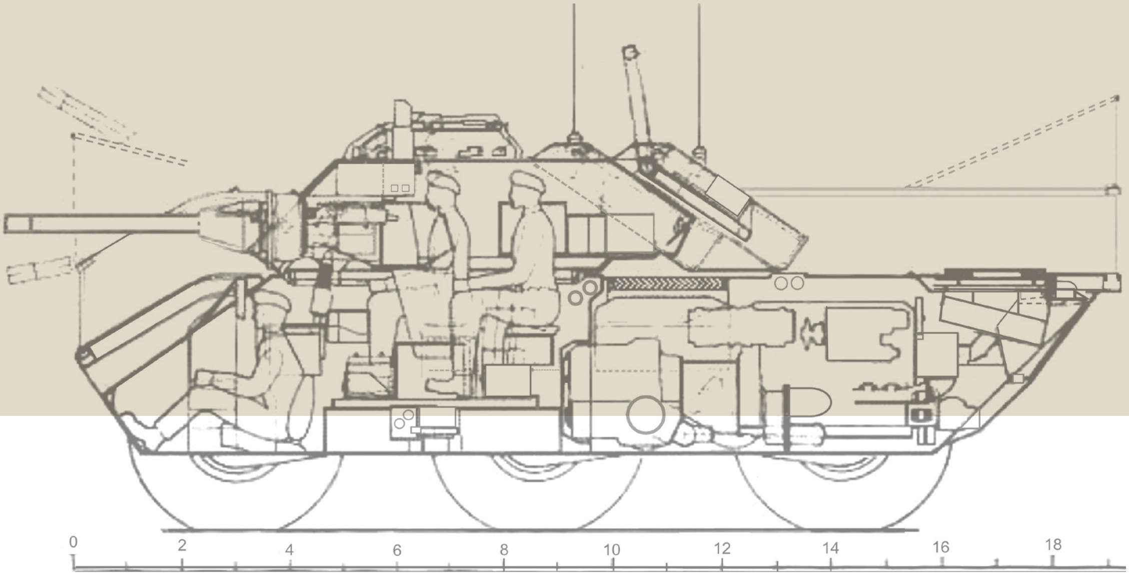
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PART 3

WHEELED AFV CONCEPTS AND DEVELOPMENT

ABOVE
AVR Scheme A side view. (Crown Copyright MOD)

SALADIN AND SARACEN

In 1946 development of the FV601, Saladin armoured car, was started. Work started in response to an Army requirement, issued in January that year, for a replacement for the Daimler Mk II and AEC Mk III armoured cars with a focus on producing a vehicle of similar dimensions to the Daimler but with improved performance. Protection was required 'to the same standard' as the Daimler. The original FVRDE concept was for a six-wheel vehicle with a crew of four and mounting a 2-pdr gun with a 'Littlejohn' adaptor to give the required armoured-piercing requirements.[16] The use of the adaptor meant that HE could not be fired; hence an improved 2-pdr gun, called 'Pipsqueak', was developed. As well as giving the required HE capability the armour-piercing performance was better than the 2-pdr with Littlejohn Adaptor due to new APDS ammunition capable of penetrating 85mm of sloped armour at 1,000 yards (914m). As the design evolved it was clear that the vehicle would be heavier than the Daimler and so the target weight was relaxed but was not to exceed 10.5 tons for air transportability. A contract for a detailed design was awarded to Alvis in October 1947 and a mock-up was completed in 1948 – designated FV601(A). It was then decided that the 2-pdr gun was not powerful enough and that the L5A1 76mm, being developed at the Armament Design Establishment at Fort Halstead, should be fitted. This weapon was not ready until 1953 which delayed the build of the first prototypes. The first 'basic prototype' was running by June 1953 with a fully representative prototype available soon after. Meanwhile Alvis was also awarded the contract for design parent of the FV603 Saracen. This was required to replace the half-track vehicles of US origin then in service and its development was planned to follow on from that of Saladin and use many of the same automotive components. Fielding of Saracen then became more urgent as it was needed to support operations in Malaya. In order for Alvis to focus on that vehicle, the six pre-production Saladin vehicles were built by Crossley Motors. The move to the larger

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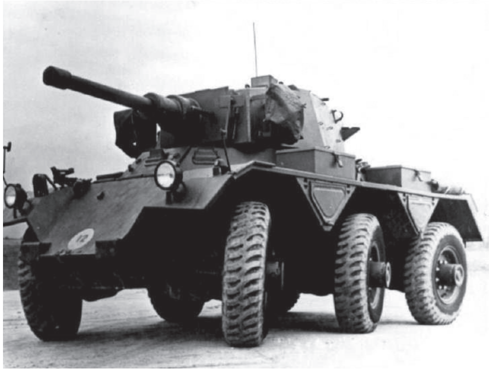
[16] The Littlejohn Adaptor was a tapered extension screwed to the end of the barrel. It was used with special ammunition consisting of tungsten wrapped in a malleable metal. As the round went down the tapper it was compressed into a smaller diameter and the driving pressure increased. This resulted in a 40 per cent increase in velocity and hence significant improvements in armour penetration.



Saladin Mark 2 Armoured Car. This vehicle was used for the User Trials of the Mark 2 Turret. (Crown Copyright MOD)

weapon meant that only two crew members could be accommodated in the turret and in the original Mark 1 version (FV601(B)) the commander also acted as the gunner. This was considered unsatisfactory by the user and so the Mark 2 turret (FV601(C)) was developed in which the second turret crew member acted as the gunner and radio operator with the commander responsible for loading the main armament. As well as the new 76mm quick-firing gun, coaxial and pintle-mounted 0.3in. machine guns were also provided, although prototypes were fitted with a 0.50in. pintle-mounted machine gun. For aiming the gunner had a 6x magnification sight with an 11-degree field of view and a fixed ballistic graticule for firing HESH and HE rounds as well as the coaxial machine gun. Forty-two rounds were carried with 11 ready rounds in the turret. The British Aircraft Corporation developed a version fitted with Swingfire missiles but this did not enter service. The vehicle had the driver's compartment at the front, a centrally mounted turret and a rear engine compartment and was of a welded steel construction with a maximum armour thickness of 32mm on the turret front. As with the Saracen and Ferret the steering wheel sloped forward which was efficient space wise and aided entry and exit for the driver. The engine was a Rolls-Royce B80 petrol engine that generated 160hp at 3,700 rpm and drove through a Daimler five-speed semi-automatic pre-select epicyclic gearbox. Reverse was selected via the transfer box so that five speeds were provided in reverse as well as forwards.

The prototypes had rear-facing driving controls for hasty moves in reverse and a light track could be fitted round the rear pairs of wheels, but neither of these capabilities was taken forward.

In spring 1956 a Saladin was delivered to the Middle East trials team in Cyprus where it remained until at least 1958 undertaking various hot weather trials. Later, in 1960, a Saladin was also sent to the Army Design Establishment in Australia for assessment trials. Saladin production started in 1958 with the first vehicles delivered in 1959. Production continued to 1972 by which time 1,177 vehicles had been made. In the British Army it equipped armoured and infantry units where it was used for reconnaissance, pursuit and security purposes. It remained in service until the early 1990s with the final vehicles being used on internal security purposes in Cyprus.

Overseas users included Bahrain, German Border Guard, Ghana, Indonesia, Jordan, Kenya, Kuwait, Lebanon, Libya, Nigeria, Oman, Portugal, Sierra Leone, Sri Lanka, Tunisia, United Arab Emirates and Yemen. The version for the German Border Guard (designated FV601(D)) had a number of modifications including revised lighting and a smaller mantlet as there was no requirement for a coaxial machine gun. In addition, Australia fitted some M113 APCs with Saladin turrets for use as close support vehicles. Although Saladin was replaced in British Army service by CVR(T) variants it continued to be used by other countries and it was notably seen defending Kuwait City during the Iraq invasion in 1990.

A swimming version was developed with a flotation screen and two such vehicles were trialled by BAOR in 1965. It had a new wing line round the vehicle to mount the camera-bellows-type screen which could be raised using a small hand winch. The screen had transparent slots for visibility.

Further developments of the Saladin were considered, leading to a proposal in 1962 outlining two new versions for potentially fielding as early as late 1964:

- The Air-Portable AFV (APAFV);
- The Air-Portable/Droppable Recce Vehicle (APRV).

The APAFV concept was for a vehicle weighing around 13.6 tons and armed with a 76mm gun and Anti-Tank Guided Weapons stowed in what were described as 'egg boxes' under armour. The use of a 105mm gun was considered but rejected due to its heavier weight. The APRV was to be slightly lighter and with provision to be equipped with a radar for surveillance purposes. This work fed into the Armoured Vehicle Reconnaissance programme described earlier to inform the wheeled concepts.

The requirement for Saracen also dated back to 1946. Alvis was awarded the development contract and completed the first prototype in 1951 with trials starting at FVRDE in July 1951. It was rushed into service with production starting in December 1952. This was still slightly later than the original plan which was to field Saracen in Malaysia by August 1952 but there were some delays due to problems with cooling, the front wheel mountings and obtaining the required machine tools and materials in time. The vehicle was constructed from armour steel and could be crewed by a driver, commander and ten dismounts. The main production version was the Mark 2 which differed from the Mark 1 in terms of minor modifications to the turret. The turret mounted a 0.3in. machine gun and an additional machine gun could be mounted on a ring over the rear hull. Like Saladin the vehicle was constructed of welded steel and the engine and much of the transmission and running gear was common, although unlike Saladin the engine was at the front.

A swimming kit was never investigated for Saracen. However, a deep wading kit, which comprised two large snorkel tubes that were fitted one each side of the engine compartment, was developed and tested.

The British Aircraft Corporation proposed a version fitted with Swingfire missiles but this did not enter service.

There was ongoing work to improve the engine cooling and habitability of Saracen with vehicle trials in Cyprus in 1957 and trials of modified engine grills in Cyprus in 1958. From 1963 onwards Saracen was replaced in some roles by FV432 but it remained in British Army service until 1993 with 30 vehicles being used in Hong Kong and a small number used by the Royal Engineers and the RAF Regiment for Explosive Ordnance Disposal roles. There were a number of different variants for the FV600 Saracen family:

- **FV602:** A command vehicle which was cancelled in 1949;
- **FV603:** Saracen APC;
- **FV603(C):** Saracen APC with reverse flow cooling for use in the Middle East;
- **FV604:** Saracen Command vehicle with no turret but map boards, revised seating and additional radios and batteries;
- **FV610:** Saracen Command Vehicle with a high-roof special equipment fits, accommodation for six personnel and a penthouse tent. This vehicle could also be equipped with FACE;
- **FV611:** Saracen Ambulance.

As well as the different variants the basic FV603 APC was designed to be reconfigurable for use in a number of different roles by removing the normal infantry seating and installing other fittings. The FV603 variants were:

- **FV603(a):** The basic APC crewed by a driver, section commander and ten dismounts. It could be converted for use as a load carrier by removing internal seating giving a capacity of 2.5 tons on road and 2 tons cross country;

- **FV603(b):** Regimental Command Vehicle with a crew consisting of a driver, two wireless operators and three officers. The vehicle was equipped with two field wireless sets and one 'B' set;
- **FV603(c):** Signals and Air Contact Team variants;
- **FV603(d):** Ambulance with a driver, one medical orderly plus three stretcher cases or eight sitting cases.

Other intended variants were FV603(e) Radar Vehicle, FV603(f) deception vehicle and FV603(g), an infantry command post. A variant of the FV610 was used to mount a radar system, the Radar GS No.9 Mark 1, or 'Robert' long-range ground surveillance radar.

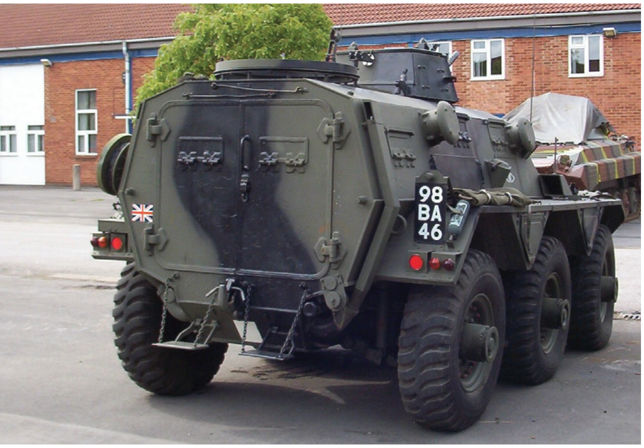
The original 1946 requirement called for an Armoured Command Vehicle (ACV), designated FV602, but this did not progress at that time. A revised requirement issued in 1949 covered ACVs for ground units and air-to-ground coordination and resulted in the FV604. Then the requirement for what became the high roof FV610 was issued in 1956 with the Royal Artillery as the main user.

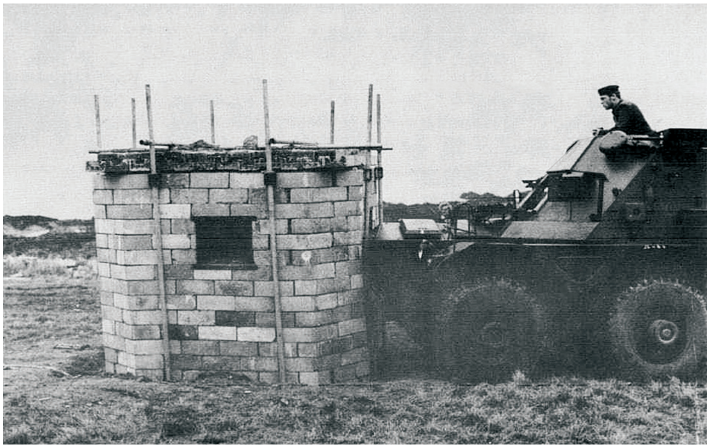
Other proposed versions were FV605, a purpose-designed ambulance, and a self-propelled 25-pdr gun variant.

Chertsey developed a range of modifications for Saracen to improve its utility and survivability for use in Northern Ireland. Not all were implemented but those that were included the fitting of additional armour protection, RPG nets, internal felt spall liners, improved seats and harnesses and run-flat tyres.

In 1976 trials were undertaken of two new alternative turrets to provide improved capabilities for internal security operations; designated Light Weapons Turret No.3 Mark A and No.3 Mark B. The improved capabilities included provision of a single shot GPMG, with associated day and image intensifier sights, an L48 Baton Gun, spotlights, still and video camera equipment and a CS gas discharger. Turret A was a basic turret designed to meet the minimum GSR requirements. Turret B was an improved turret (described as a research turret) developed by MVEE; this had a number of benefits over Turret A, including:

Front view of FV601 Saladin armoured car. (Author's Collection)



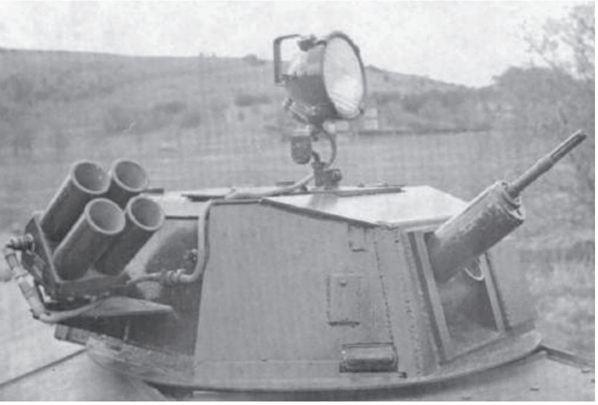


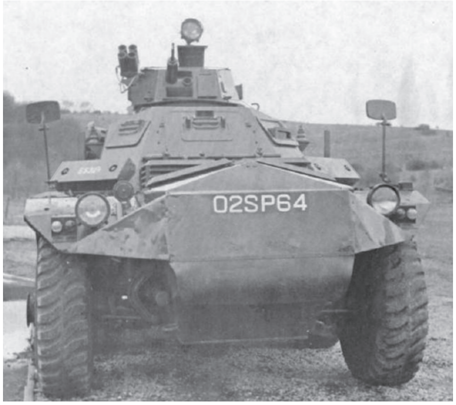
ABOVE LEFT
Saracen, rear view showing access doors for the dismounts. (Author's Collection)

ABOVE
FV610 being used to test a field fortification concept. (Crown Copyright MOD)

- Four vision blocks rather than one;
- A seat mounted on the turret ring rather than vehicle floor;
- Improved race ring and a modified FV432 GPMG turret traverse gearbox – Turret A was traversed by the turret crewman using his shoulders;
- Improved spotlight.

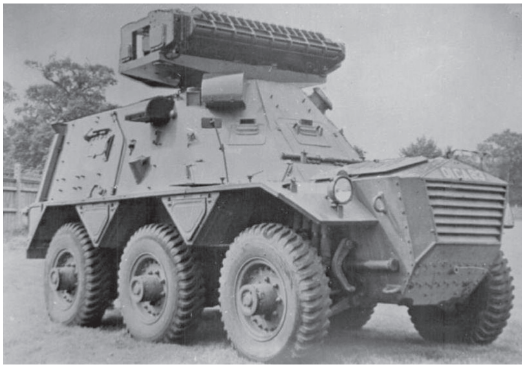
Turret B was recommended for fielding with modifications but this was not taken forward. However, spotlights and CS dischargers were fitted to standard Saracen Turrets. In addition, water cannon variants of Saracen were developed for internal security operations. As well as conventional water cannon a vehicle was developed, called a 'Special Water Dispenser', that could fire 'slugs' of water very accurately out to around 40m and was intended to target individuals. A visual-based range-finding system was used to assess the distance to the target in order to control the firing





LEFT
Internal security Saracen research turret fitted to a Chertsey Trials vehicle. (Crown Copyright MOD)

FAR LEFT
Alternative Saracen Turret A, optimized for Internal Security operations. (Crown Copyright MOD)



FV610 with No.9 Mark 1 Radar. (Crown Copyright MOD)

impulse. Six vehicles were built, one of which is on display at the Bovington Tank Museum. They were never used operationally although further work was carried out on their use for disrupting improvised explosive devices.

A number of the modifications made to UK vehicles were also implemented on those used by the Royal Hong Kong police. There a number of additional local modifications were made, including a 12v electrification system (to deter people climbing on the vehicle), a riot gun mount, petrol bomb protection and a barricade pusher.

In addition to official modifications a variety of local modifications were implemented by units operating vehicles; for example one vehicle was fitted with mine rollers for airfield force protection, and a number of vehicles had the turret removed and recoilless anti-tank guns added.

The Saracen was widely sold abroad with users including Indonesia, Jordan, Kuwait, Lebanon, Libya, Nigeria, Qatar, South Africa, Sudan, Thailand and UAE. Some of the vehicles supplied to Kuwait were different in configuration, having an open roof.

FERRET

The Fighting Vehicles Research and Development Establishment also supported the development of the 'FV701 Scout Car Liaison', or Ferret, armoured car to meet an Army requirement drawn up in 1947 for a vehicle to replace World War II designs. A mock-up was completed in 1948 and this was made available to the Army in July of that year for assessment and stowage trials. Full design work was started in 1949 with Daimler appointed as the design parent. Constructed of welded armour plate the design was an evolution of the successful Daimler Dingo and followed the same low silhouette compact layout which was facilitated by an 'H' configuration drive train with a central differential. The first prototype was completed in 1950 and, following development trials, six pre-production vehicles were manufactured. The Mark 1, which was initially designated FV701(a), was an open-top vehicle and was followed by the development of the Mark 2 (FV701(b)) which had a turret. It was originally intended that the Ferret Mark 2 should have the same turret as the Saracen but this was soon replaced as it was considered too small. Then, following the user assessment of the initial prototypes, it was requested that the height of the turret on the Mark 2 be reduced, leading to a further redesign. Ferret entered production in 1952 with the Mark 2 actually being first off the production line in October that year, followed by the first Mark 1 in December. The Mark 1 was armed with a pintle-mounted Bren light machine gun. The Fighting Vehicles Research and Development Establishment also developed a modified mounting bracket for an L7A1 or L8A1 GPMG which was tested by the Infantry Trials and Development wing in 1967. The Mark 2 mounted a .30 L3A4 Browning or L4A4 7.62 machine gun in its turret. The vehicle was powered by a Rolls-Royce B60 engine mounted at the rear, with the driver at the front. Well-sloped armour provided protection against small-arms fire and fragments. The open crew compartment of the Mark 1 was seen as a disadvantage and so a modification was developed to extend the superstructure upwards by 200mm which was then provided with an armoured hatch; this version was designated the Mark 1/2 (or FV704). Some Mark 1/2s were later modified again by mounting a turret on top of the extended superstructure. A number of upgrades to the Mark 2 were developed including the Mark 2/3 with increased hull armour and the Mark 2/4 with increased turret protection. In addition, improvements to the suspension were also developed. FV701(H) was a Mark 2/3 adapted to carry the ZB298 ground surveillance radar. This could be mounted on the turret when in use or stowed under armour for transportation.

The FV703 (or Mark 2/6) was equipped with Vigilant[17] anti-tank missiles; with two ready-to-fire missiles, one either side of the turret, and two stowed in a bin on the hull side which replaced the spare wheel stowage. The missiles could be fired and controlled by the commander from inside the vehicle or from a separate location using a combined sight and controller linked back to the vehicle via a cable. The FV703 was not the only version of the Mark 2 to be fitted with anti-tank missiles; in 1963 the Canadian Army developed a system for mounting four Entac ATGW missiles, two each side of a Ferret Mark 1. The resulting vehicle undertook 28 test firings in April 1964 at Camp Meaford.

The Ferret Mark 1(C) was a Mark 1 fitted with a deep wading kit which enabled the vehicle to ford to depths of 5 feet (1.5m). The kit consisted of additional sealing equipment, extending bellows attached to the open crew compartment and an engine air inlet duct. A swimming kit was also developed for the Mark 1/1 which consisted of a camera-bellows-type screen, with transparent vision slots, which was mounted over the open crew compartment and could be quickly raised and lowered by the crew. New watertight stowage lockers were provided between the wheels and below the bottom of the screen. Both a deep wading fit and a flotation kit were developed for the Mark 2 which, unlike other flotation kits used on UK AFVs at the time, consisted of three rubberized inflatable bags.

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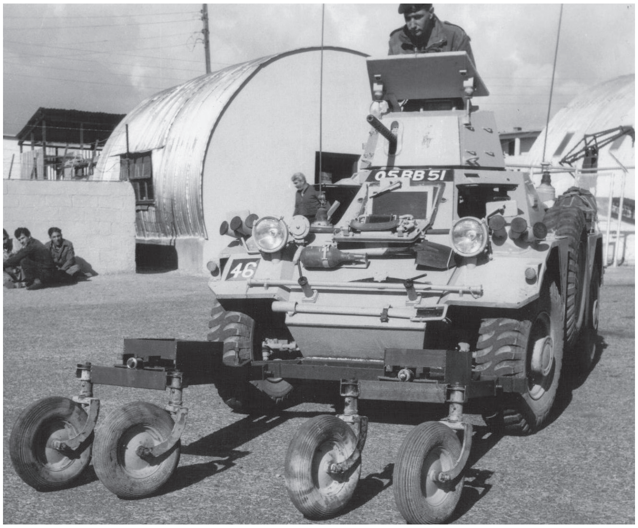
[17] Visually Guided Light Anti-Tank.

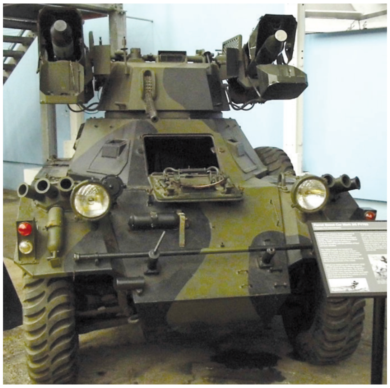

Ferret Mark 2 with lightweight mine roller (note vehicle is reversing). (Author's Collection)

The Daimler Company built 4,409 vehicles of various Marks and they were used by 31 different countries with Australia, Canada, France and South Africa all fielding significant numbers. In 1953 prototype No.2 was sent to Fort Knox for testing by the US Army but this did not result in any orders. In the interest of commonality, the Ferret used the same engine as the Humber 1-ton vehicle and some of the suspension components were common to the FV600 series.

A cold weather kit was developed for Ferret Mark 1 and tested in Canada over the winter of 1956/57. As well as a weather shield and the use of special low temperature lubricants the vehicle was fitted with an improved heater and a heater and insulation for the batteries. The vehicle was able to start and operate at the temperatures of -32°C which were experienced during the trial.

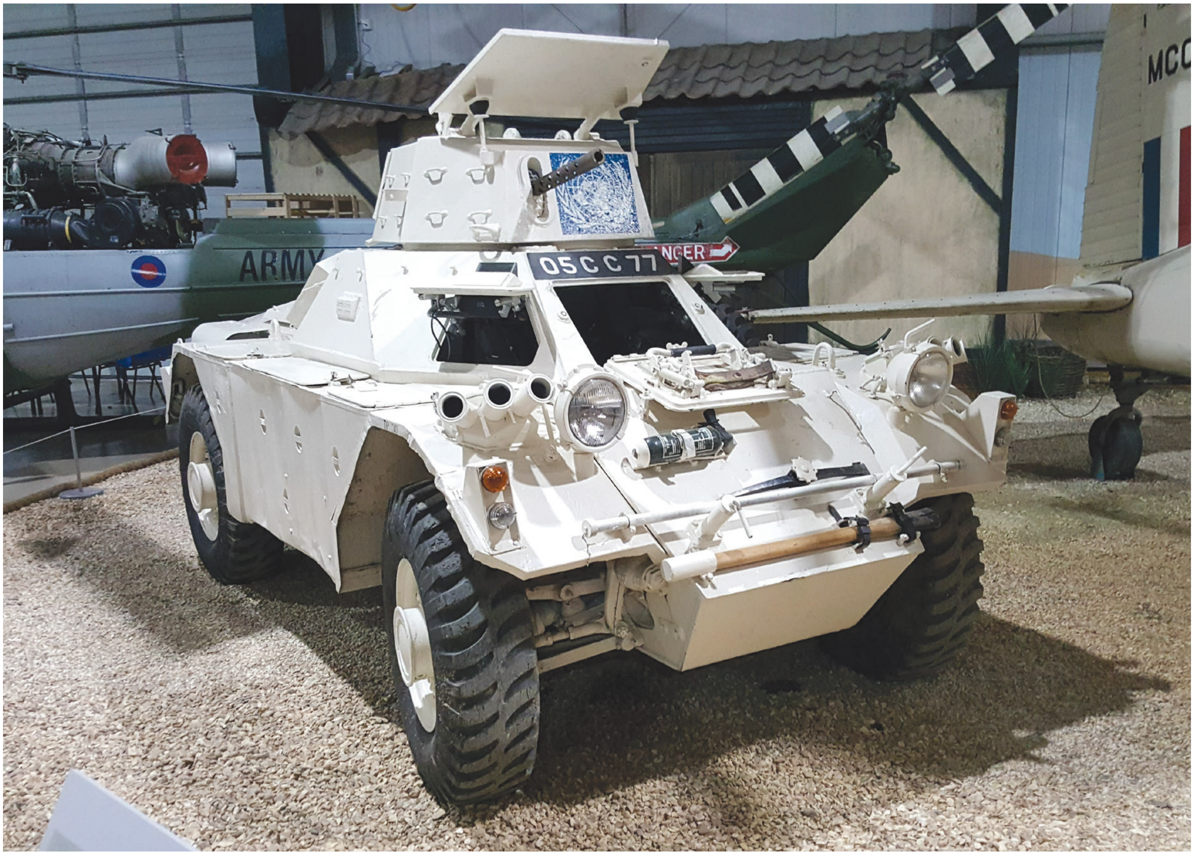
In 1963 FVRDE responded to a request to improve the automotive and swimming capabilities of the vehicle. Six prototypes of an improved Ferret vehicle were therefore built by modifying standard vehicles. The major changes included fitting larger aluminium wheels, improved brakes and suspension and a permanent flotation screen. Other changes were intended to reduce the servicing requirements. Following user trials at Bovington further modifications were made and the vehicle then went into production. The redesigned hull was designated the Mark 3 and production vehicles fitted with the standard turret were designated Ferret

Mark 4 (FV711), commonly called the 'Big Wheeled Ferret'. In 1967 FVRDE started work on the Ferret Mark 5 (FV712) which mounted a new turret with four BAC Swingfire anti-tank missiles on the Mark 3 hull. Approval for service use was given in August 1970 and although only 32 Mark 5s were manufactured, by Alvis, it was noteworthy in being the first example of the use of aluminium armour on a fielded UK vehicle. Aluminium was used to minimize the increase in weight due to the new turret but FV712 was still nearly 0.5 tonnes heavier than the FV711. FV712 was approved for full service use in August 1970. The Ferret Mark 5 retained the two-man crew of the other versions and, as with FV438, the missile launcher could be operated



LEFT
FV703 with Vigilant missiles, on display at the Bovington Tank Museum. (Author's Collection)

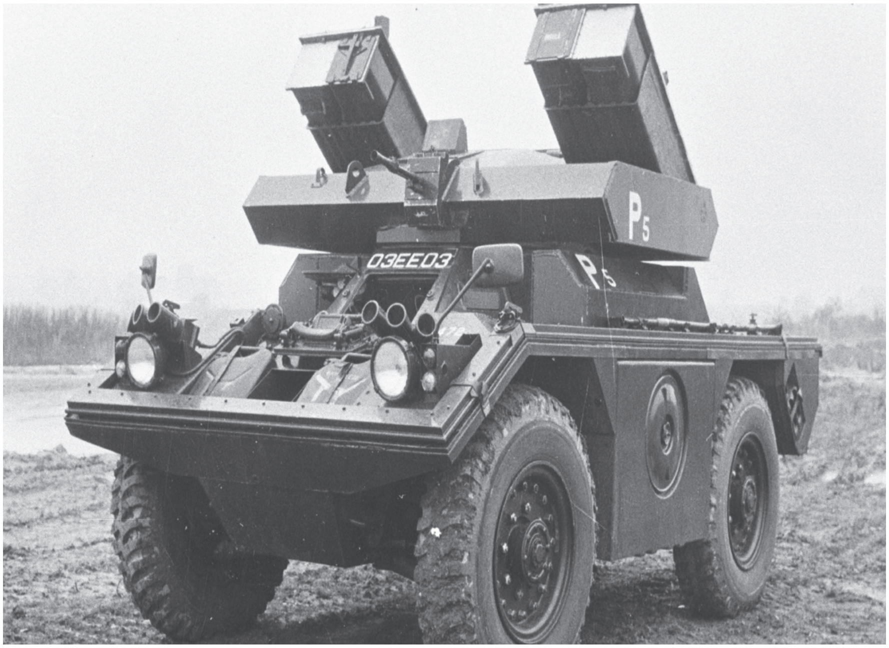
BELOW
Ferret Mark 2 in United Nations' colours at the Museum of Army Flying. (Author's Collection)

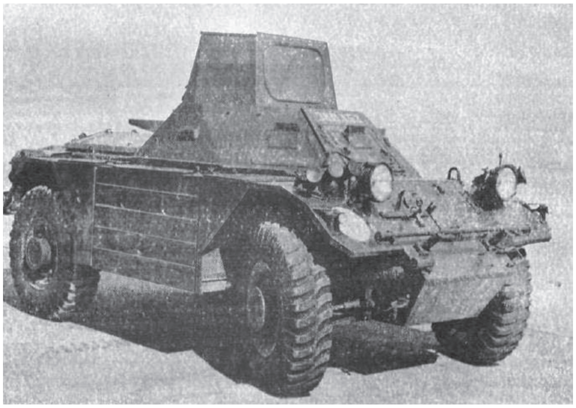


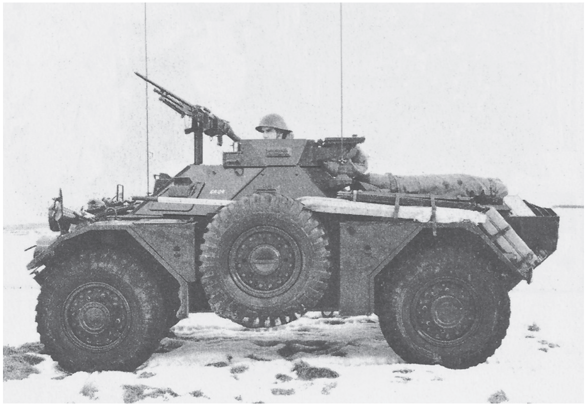
RIGHT
Ferret Mark 5 prototype armed with Swingfire anti-tank missiles. (The Tank Museum, Bovington)

BELOW
A poor-quality picture taken from the report of Ferret Mark 1 cold weather trials in Canada with an extended weather shield over the crew compartment. (Crown Copyright MOD)

BELOW RIGHT
A Ferret Mark 1/II. (Crown Copyright MOD)







from a remote position up to 50m from the vehicle. In trials it took around five minutes for the commander and driver to ready the vehicle and deploy the remote launch and guidance controller. An additional two spare missiles were stowed in the hull.

Following a successful demonstration of the use of a Carl Gustaf by dismounts to launch illuminating rounds a trial was carried out in 1963 into the feasibility of mounting a Carl Gustaf launcher on the side of a Ferret turret for this purpose. The launcher tube was mounted on the left-hand side of the turret where it could be loaded by the turret operator. It could elevate up to an angle of 25 degrees. It was aimed in azimuth by turning the turret but the arc was limited by the need to prevent damage to the rear engine compartment decks. Twelve rounds of ammunition, which could be fired out to 2,300m, could be carried if other stowage items were removed. Although the trials were successful the system was never fielded.

Alvis Ltd developed an export vehicle called Ferret 80 which utilized the Ferret Mark 4 wheels and suspension but had an aluminium hull and was fitted with a Perkins T6-3544 diesel engine rated at 116kW. It was offered in a number of configurations including with two or three crew members and armed with machine guns or a 20mm cannon.

The Ferret remained in British Army service for over 40 years. It saw action as late as 1991 during Operation *Granby* and 60 were still based in Cyprus in 1992 for internal security operations.

WHEELED ARMOURED VEHICLE RECONNAISSANCE CONCEPTS

As discussed previously, in 1961 FVRDE started to develop both wheeled and tracked concepts for the AVR to meet the requirements of GSR 1010. At the time there was a separate requirement, GSR 1006, for an air-portable AFV; however, following feasibility studies it was agreed on 7 December 1962 that the requirements would be combined and GSR 1010 was revised. The revised requirement, issued in January 1963, was for an air-droppable platform with mobility 'as good as Ferret', an armament equivalent to Saladin, passive night vision and the ability to be adapted to other roles besides reconnaissance. There was also a requirement to carry long-range anti-tank missiles with an effective range out to 4,000m. The 'air droppable' requirement limited weight to 13.6 tons. The project study for the wheeled version, which reported in December 1963, presented two main concepts, called Scheme A1 and Scheme A2. These were both for a 6x6 vehicle armed with Swingfire missiles and a 76mm gun, weighing around 13.6 tons. They were to be powered by a 300hp K60 engine and use skid steer as demonstrated on the TV1000 6x6 high-performance demonstrator.

TV1000, also called Rhinoceros or Rhino, had been designed and built in 1956–57 as a mobility test rig to assess potential technologies for future wheeled vehicles, including a possible wheeled version of 'Contentious'. It was a 6x6 vehicle with a 535hp Meteorite engine and at the time was the world's most powerful all-wheel-drive vehicle. It was skid steer and fitted with very large tyres with a central tyre inflation system. This allowed the tyre pressure to be reduced to increase the contact patch for running on soft ground. The skid steer solution meant that there was no requirement to restrict the width of the lower hull to allow room for the steered wheels to turn and this allowed the designs to be shorter and lighter compared with vehicles with a conventional steering solution. TV1000 did successfully demonstrate the viability of skid steer and undertook a run from Chertsey to Kirkcudbright in Scotland as part of its testing; however, user concerns about the use of skid steer remained, even though the feasibility study report pointed out that such a system had been successfully used on the World War II Terrapin amphibious vehicle.

Frontal armour of the concept vehicles was to be proof against 14.5mm heavy machine gun rounds and, to maximize protection on the turret, the upper and lower sides were sloped at 45 degrees. The main difference between the two concepts was in the location of the ATGW missiles; Scheme A1 mounted four missiles in the rear of the turret and Scheme A2 mounted them in the hull. Both concepts had provision to be fitted with additional externally mounted missiles to meet the support role defined for the air-portable AFV role. Despite the best efforts of the Chertsey design the concepts still exceeded the 13.6-ton target weight and so were regarded as being too heavy; hence two further concepts were explored. The first was a driver in the turret solution, called 'Scheme B'. This was rejected as it only gave a weight saving of 272kg and solutions for driving from the turret were not mature. The second new concept, called 'Scheme C', was for a three-man crew vehicle with the main armament mounted in a barbet giving a total of 80 degrees traverse. As designed the vehicles were to be manufactured from steel but work had already started on aluminium as an alternative and ballistic trials on rigs representing the proposed hull and turret configurations had started. As with the tracked AVR concept none of the schemes was taken forward as they were considered too heavy.

The basic data for Schemes AVR A and C are shown in Table 8.

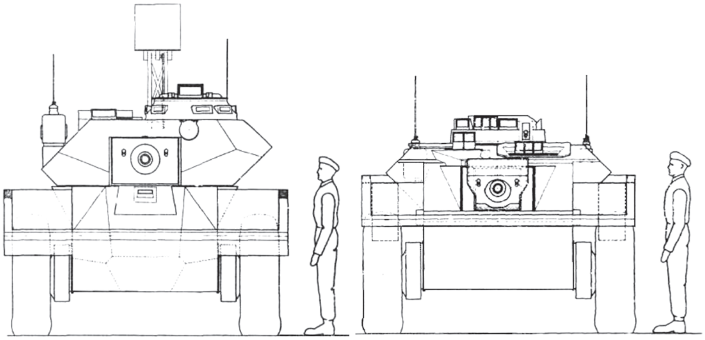
Table 8: **AVR Scheme A and Scheme C Data**

	Scheme A	**Scheme C**
Length, Hull/m	5,944	5,918
Length, Total/m	6,350	6,553
Width/m	2,845	2,540
Height/m	2,464	2,134
Weight: AVR version/kg	14,107	13,536
Weight: AVR support/kg	14,400	13,800
Ground clearance/m	432mm	
Engine	RR K60 rated at 300hp	
Suspension	Torsion bars with 406mm movement	

FOX AND VIXEN

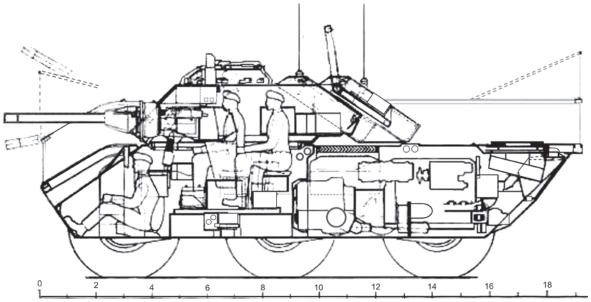
A new requirement, GSR 3301, for an Armoured Reconnaissance Vehicle was issued in August 1964. It called for a wheeled or tracked solution at around 6 tons. Two different wheeled concepts were proposed for what was called AVR(light) which carried over features from the previous AVR designs; both had six-wheel skid steer and mounted a 76mm gun but one was 6 tons and the other 8 tons. There remained doubts about the viability of skid steer and the tracked solution was selected and developed as CVR(T).

The army still had a requirement for a replacement for Ferret and in June 1965 GSR 3358 for Combat Vehicle Reconnaissance (Wheeled), (CVR(W)), was issued. CVR(T) was the main development focus at that time and so manpower and financial resources for this project were therefore limited. GSR 3358 defined the requirements against which FVRDE carried out studies into concepts. These were based on evolutions of Saladin and the Ferret Mark 4 design. In March 1965 it was agreed that the future studies would focus on variants of the 'Big Wheel Ferret' with the 6x6 version not being taken forward as it would require more development effort. A feasibility study was therefore carried out by FVRDE into the new vehicle running from March to August 1965; following this, work started in September with Daimler Ltd on the initial design phase. The study recommended two alternative Ferret options to the Army. These were designated Ferret Mark 5, which was an all-steel vehicle with a one-man turret, and Ferret Mark 6, which was a more



AVR Scheme A (left) and Scheme C (right). (Crown Copyright MOD)

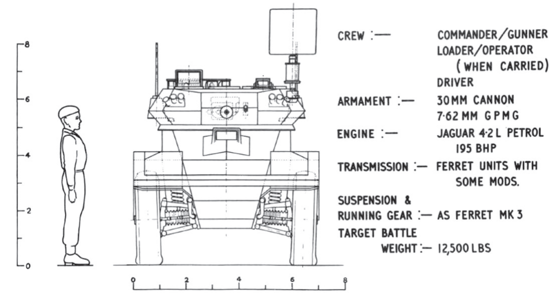
radical evolution with an aluminium hull and two-man turret. In October the Mark 6 concept was selected to meet the CVR(W) requirement and on 22 October 1965 a further contract was placed on Daimler Ltd to work with FVRDE on the detailed design; this ran to April 1966. To support the project study a full-scale mock-up was built. In April 1966, a contract for full development was placed. The resulting vehicle was designated the 'Fox' armoured car. It used the same Jaguar XK engine as CVR(T) and had a new two-man turret. The turret configuration was based on the concept design proposed for the wheeled AVR light which was similar to that being developed for CVR(T). The additional hull stiffness, due to the use of the thicker aluminium plates, was exploited to remove the stiffening tube in the engine compartment of Ferret and hence improve engine access. The Fox also had a much larger turret ring than Ferret – 50in. rather than 29in. to accommodate a turret large enough for the two-man crew and 30mm RARDEN cannon. The first prototype was delivered in 1967 – a year before CVR(T); there was a degree of competition between the wheeled and tracked vehicle departments at FVRDE and so delivering the CVR(W) prototype first was seen as a victory by the team responsible. A further 14 prototypes were built with the last being delivered in April 1969. Nine prototypes were used by FVRDE for development testing and the other five were designated for user trials which started in August 1968. The other vehicle was retained by Daimler for their own development trials. In addition to the prototypes the contract with Daimler included the delivery of a hull for ballistic testing and an engine and cooling test rig. The vehicle was accepted for service in July 1970. This was some 18 months later than originally planned due to delays in prototype build and late delivery of sights and weapons. In addition, time was taken to address a number of performance and reliability issues highlighted during trials.

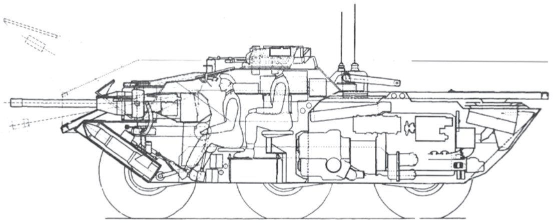


AVR Scheme A side view. (Crown Copyright MOD)

The production contract was not awarded to Daimler but was placed with ROF Leeds. This meant that when Ferret production at Daimler finished, the last major link between UK AFV development and the commercial automotive market was broken. Daimler had had a long involvement in armoured vehicles and had provided the chassis and engines for the first Simms armoured car in 1899 and engines for the first operational British tanks.

As well as the manufacture of Fox, ROF Leeds also developed alternative versions for export with a crew of two, including:


CREW :— COMMANDER/GUNNER
LOADER/OPERATOR (WHEN CARRIED)
DRIVER
ARMAMENT :— 30MM CANNON
7·62 MM GPMG
ENGINE :— JAGUAR 4·2 L PETROL
195 BHP
TRANSMISSION :— FERRET UNITS WITH SOME MODS.
SUSPENSION & RUNNING GEAR :— AS FERRET MK 3
TARGET BATTLE WEIGHT :— 12,500 LBS



TOP
CVR(W) Concept 'Ferret Mark 6'. (Crown Copyright MOD)

ABOVE
AVR Scheme C side view. (Crown Copyright MOD)

- The Panga armed with a 0.5in. Browning machine gun;
- Fox 25mm armed with a Hughes 25mm cannon and a 7.62mm machine gun;
- Fox-Milan armed with twin Milan launchers and a 7.62mm machine gun.

In addition to the turreted version of Fox a liaison vehicle with an additional crew space was developed to meet the role covered by the Ferret Mark 1. The original concept was for a Fox hull with a higher roof line but this was rejected; hence, a 'Fat Fox' concept with a wider and lower hull was developed rather than a 'Tall Fox' concept.

Called Vixen, it was designed for use as a command and liaison platform in airmobile and mechanized units for Royal Armoured Corps, Royal Artillery, Engineers, Signals, Infantry and REME users. It could carry a crew of up to four consisting of a Commander, Driver, Radio Operator and Passenger, although the operational crew varied from two to four depending on its role. Specific stowage fits were developed for the following roles:

- Air-portable reconnaissance platoon;
- Mechanised Commanding Officer;
- Mechanised Company Commander;
- Mechanised Regiment Signals Officer;
- Mechanised Anti-Tank Platoon Commander;
- Mechanised Assault Pioneer Platoon Commander.

Prototype FV721 Fox armoured car. (Crown Copyright MOD)

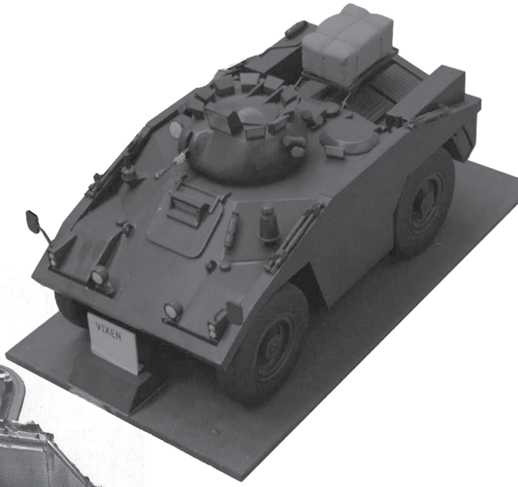
CVR(W) Fox used for survivability trials. (Crown Copyright MOD)

The weight of the basic vehicle without role-specific stowage was 5,839kg and the battle weight varied from 6,259kg for the Anti-Tank Platoon Commander role to 6,510kg for the Mechanised Commanding Officer. The basic fixed radio fit was for a VRC 353 with two radios fitted for the signals role.

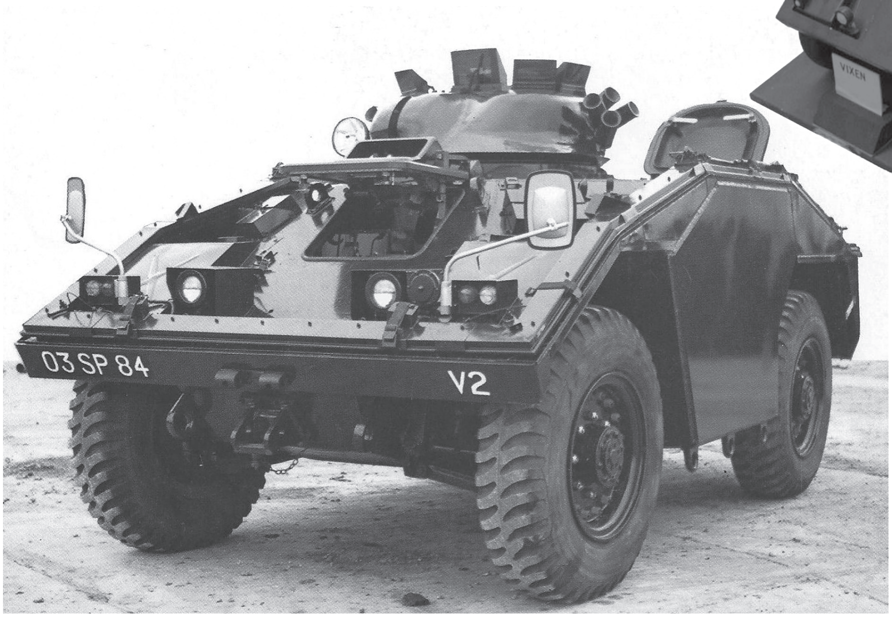
Vixen was fitted with a small turret armed with an L37A1 GPMG for which 2,000 rounds of ammunition could be carried. Smoke grenade launchers were also fitted. Prototype trials vehicles were fitted with an improved 'Mark 2' turret but a Mark 3 design was also developed which provided increased room for the commander. The turret was equipped with a Sight Periscope AV No.64 combined day/image intensifier sight and the driver was provided with a day periscope AFV No.48 Mark 2 and an image intensifier (II) swap sight for night driving.

The design was accepted in 1970 and a contract to build prototypes placed with ROF Leeds in 1971; however, it never went into production having been cancelled as part of defence cuts in 1974.

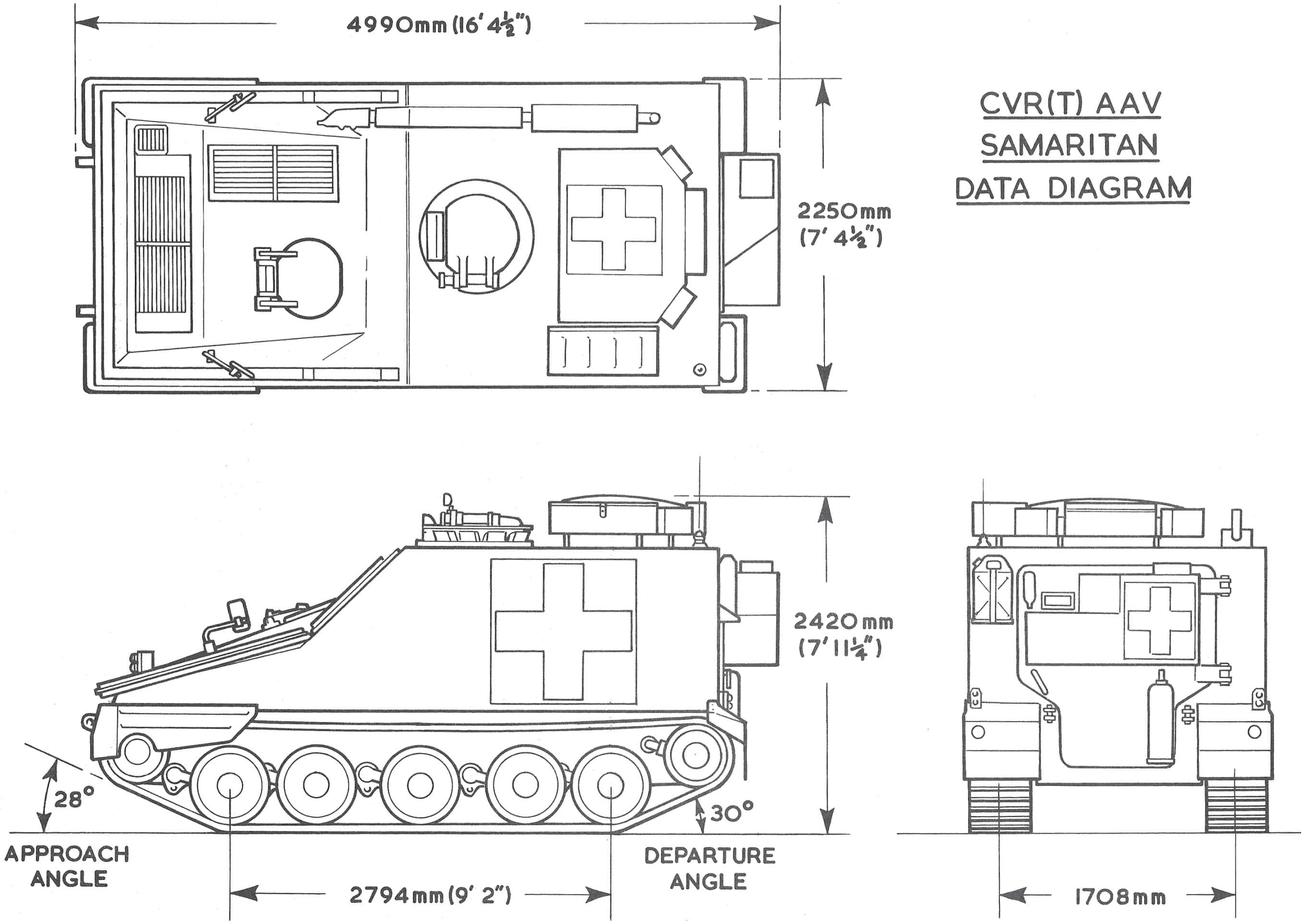
Fox was the last wheeled armoured vehicle developed at Chertsey to enter service, although the establishment did support the development of armoured wheeled vehicles for internal security use, including the Snatch Land Rover for which the establishment's expertise in armour grade composites was exploited.

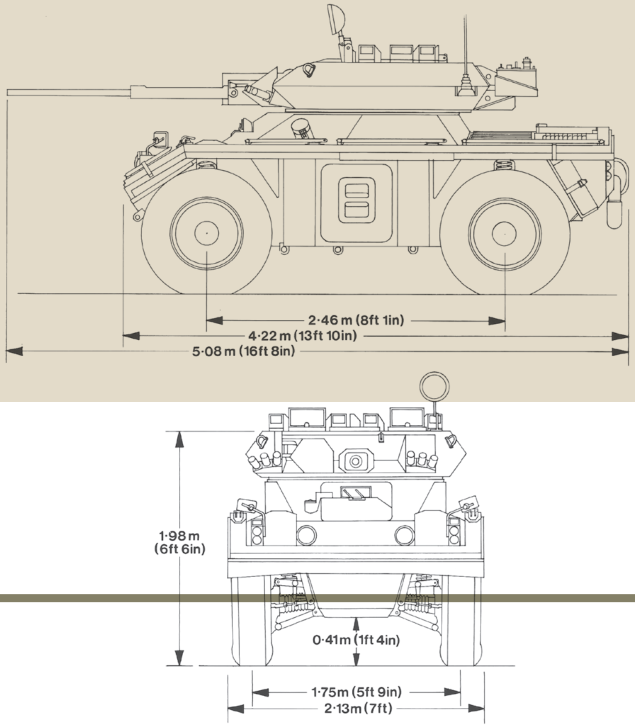


ABOVE
Model of Vixen made by the Chertsey Pattern Shop. (Crown Copyright MOD)



LEFT
Vixen liaison vehicle prototype. (Crown Copyright MOD)


4990mm (16' 4½")
CVR(T) AAV
SAMARITAN
DATA DIAGRAM
2250mm
(7' 4½")
2420mm
(7' 11¼")
28°
APPROACH
ANGLE
30°
DEPARTURE
ANGLE
2794mm (9' 2")
1708mm


2·46 m (8ft 1in)
4·22 m (13ft 10in)
5·08 m (16ft 8in)
1·98 m (6ft 6in)
0·41m (1ft 4in)
1·75m (5ft 9in)
2·13m (7ft)

PART 4

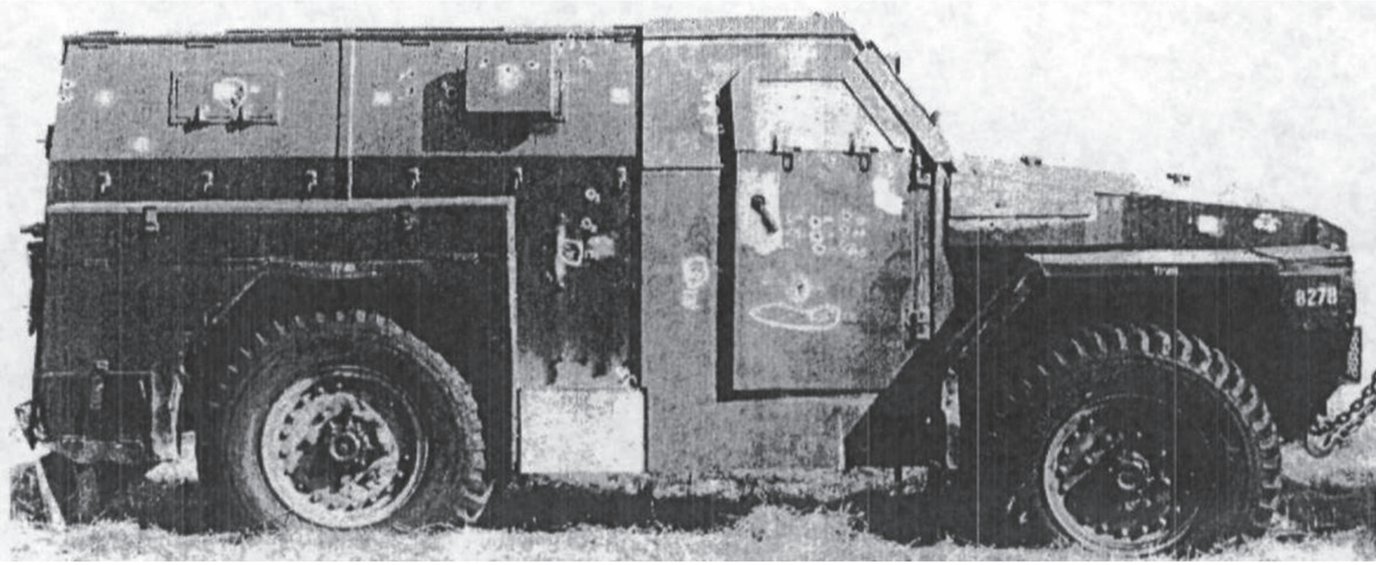
OTHER BRITISH ARMOURED VEHICLES OF THE COLD WAR ERA

ABOVE
FV721 Fox dimensions.
(Crown Copyright MOD)

The establishment at Chertsey had a role in supporting the development or testing of all vehicles entering British Army use and hence supported other armoured vehicles although not as design authority. In other cases, technologies and sub-systems based on research and development at Chertsey were used in vehicles. Some of the more significant examples are outlined below.

1-TON ARMOURED 4X4 HUMBER

The FV1611 1-ton armoured 4x4 vehicle was originally developed as a stopgap to provide an interim capability until the Saracen was available in sufficient numbers. It was based on the FV1600 Humber 1-ton trucks of which around 3,700 were manufactured between 1952 and 1955. One intended variant was an armoured version planned to be used by a range of army users in 17 different configurations. A contract was placed with Joseph Sankey in 1952 and a wooden mock-up then built for approval. Three prototypes were built, with the first delivered in June 1956, and then a further 20 pre-production vehicles for user trials. The vehicle only had limited armour protection and no roof protection and so FVRDE developed a bolt-on armoured roof kit. In 1958 the decision was made to produce fully armoured versions of the FV1601 general service truck and


Uparmoured Pig used for protection validation trials. (Crown Copyright MOD)

the FV1602 radio truck, designated FV1611 and 1612 respectively. The Humber chassis was retained and the armoured bodies manufactured by Royal Ordnance Factories and Joseph Sankey. The FV1611 was used for troop or cargo transport and could carry up to eight passengers. FV1612 carried radio equipment and was manned by a driver, commander and radio operator. An ambulance version was also manufactured, FV1613, which could carry up to three stretcher cases plus a medical orderly. FV1611 was used by the Army and the Royal Ulster Constabulary.

FV1620 was a Malkara missile launch vehicle which carried four wire-guided missiles, two ready to fire and two stowed. The Fighting Vehicles Research and Development Establishment was responsible for much of the missile system integration and development of the crew controls. It served with airborne battalions.

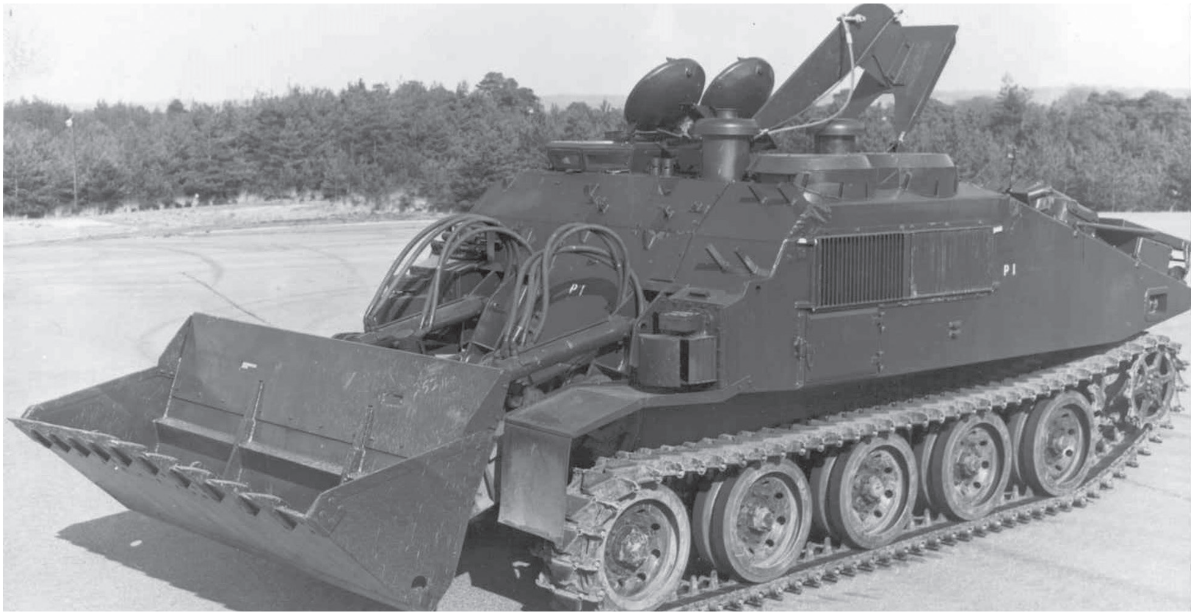
FV1611 went out of British Army service in the late 1960s, however, its characteristics, being a small-wheeled vehicle shaped like a lorry, made it very suitable for use during the troubles in Northern Ireland, providing protected transport for personnel and equipment. Around 500 were therefore rapidly brought back into service. The vehicles were modified with increased projection, barricade rams and improved seats and harnesses and in the modified form were known as ‘Pigs’. Chertsey supported the development of a number of specialist variants and associated automotive upgrades to carry the additional weight, including:

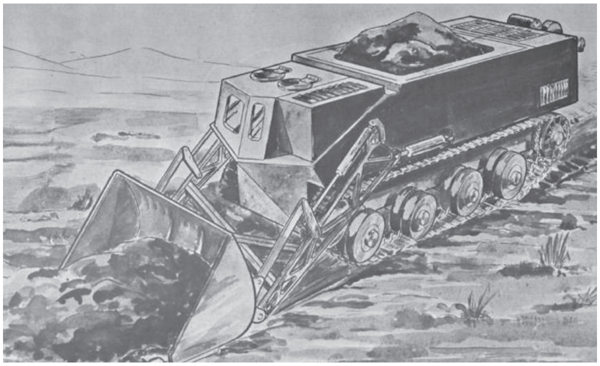
- Flying Pig: a normal vehicle with extending riot screens either side;
- Holy Pig: rooftop hatch surrounded by Perspex screen – likened to the Popemobile;
- Kremlin Pig: wire screening for protection against rocket-propelled grenades;
- Squirt Pig: fitted with a water cannon beside the driver for riot control;
- Foaming Pig: fitted with a foam generator to suppress explosive blast;
- Felix Pig: modified for Explosive Ordnance Disposal (EOD) duties.

In light of the increasing threat encountered in operations in Northern Ireland Chertsey undertook an exercise to increase the armour protection levels of the ‘Pig’ to defeat armour-piercing rounds. The up-armouring scheme was extensively tested but not fielded.

FV180 COMBAT ENGINEER TRACTOR

The Combat Engineer Tractor (CET) was developed at the Military Engineering Experimental Establishment at Christchurch which amalgamated with FVRDE in April 1970 to form MVEE. The project started in the early 1960s with a General Staff Requirement being issued in 1962. The intention was for CET to replace the light and medium wheeled tractors in Field Squadrons of the Royal Engineers and provide the benefits of armour protection against small arms and artillery fragments, NBC collective protection, improved mobility and a swimming capability. Feasibility studies were carried out in conjunction with industry which reported in April 1965. Responsibility for the power pack, transmission and running gear was with FVRDE, while MEXE had responsibility for all other sub-systems and the overall system. Two pre-prototype test rigs were completed by 1968 and these were used to inform an interim PD report in 1969. It was originally intended as a multinational programme with Germany as a main partner, but this did not materialize, hence it became a UK-only development. Following extensive testing and development two further prototypes were delivered in late 1973 and early 1974. Production


Prototype FV180 Combat Engineer Tractor. (Crown Copyright MOD)



Combat Engineer Tractor concept from the Feasibility Study report. (Crown Copyright MOD)

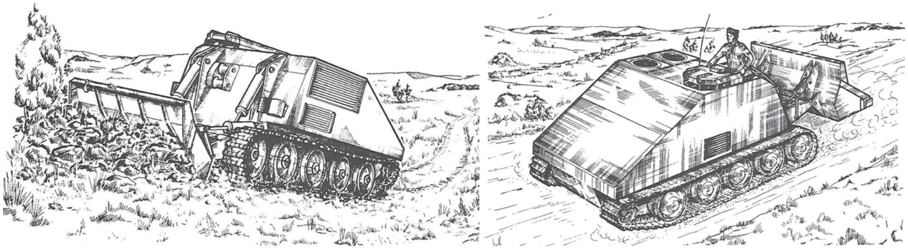
started at ROF Nottingham in 1977 with the first vehicle delivered in May 1978.

The CET was designed for dozing and earth moving. It had a two-speed winch for the recovery of other vehicles and could deploy a rocket-propelled earth anchor for self-recovery. The vehicle could also carry fascines or trackway and could be fitted with a jib attachment. It was amphibious, driven by two Doughty water jets. It had an aluminium hull and full NBC collective protection. It was manned by a crew of two who sat in a tandem arrangement but facing in opposite directions so that either could drive the vehicle. The bucket had a capacity of 1.91 cubic metres and could be fitted with blades for lifting pallets. CET was also procured by India and Singapore.

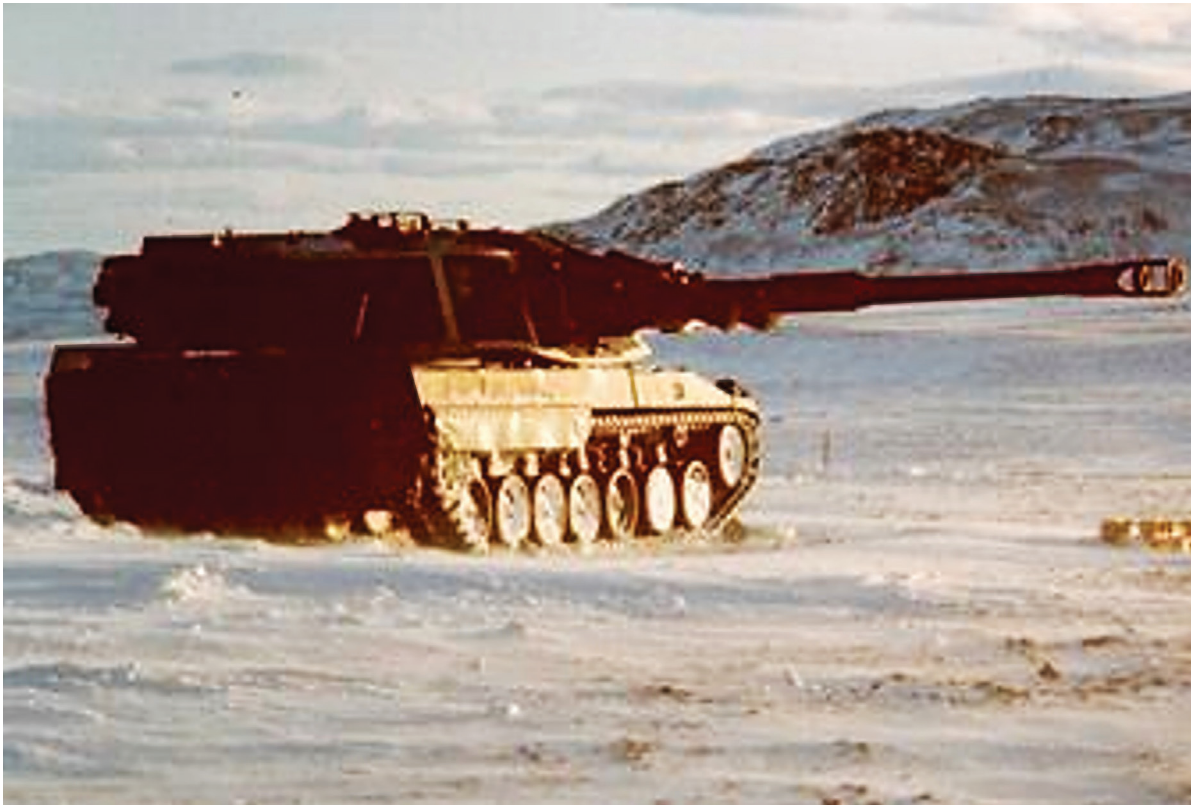
In British Army service it has been replaced by the Terrier engineer vehicle developed by BAE Systems.

Main Characteristics:

Weight: 17,700kg
Overall length: 7.30m
Hull length: 5.334m
Height: 3.41m
Width over hull: 2.87m
Width over bucket: 2.921m
Maximum road speed: 56kph
Maximum water speed: 2.5m/s
Range: 320km
Vertical obstacle: 0.61m
Gradient: 60 per cent
Gap crossing: 2.06m



Artist impressions of the final Combat Engineer Tractor concept. (Crown Copyright MOD)

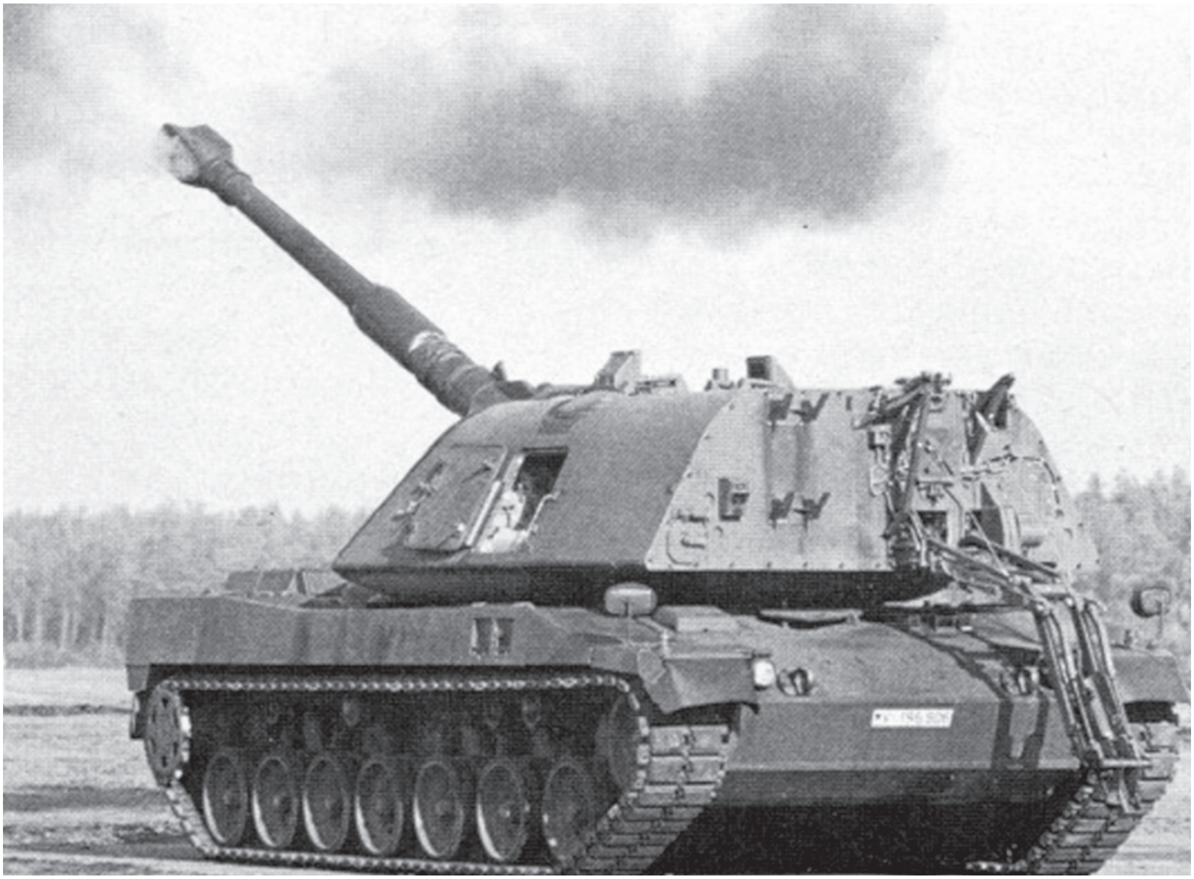


SP70 during Chertsey run cold weather trials in Norway. (Crown Copyright MOD)

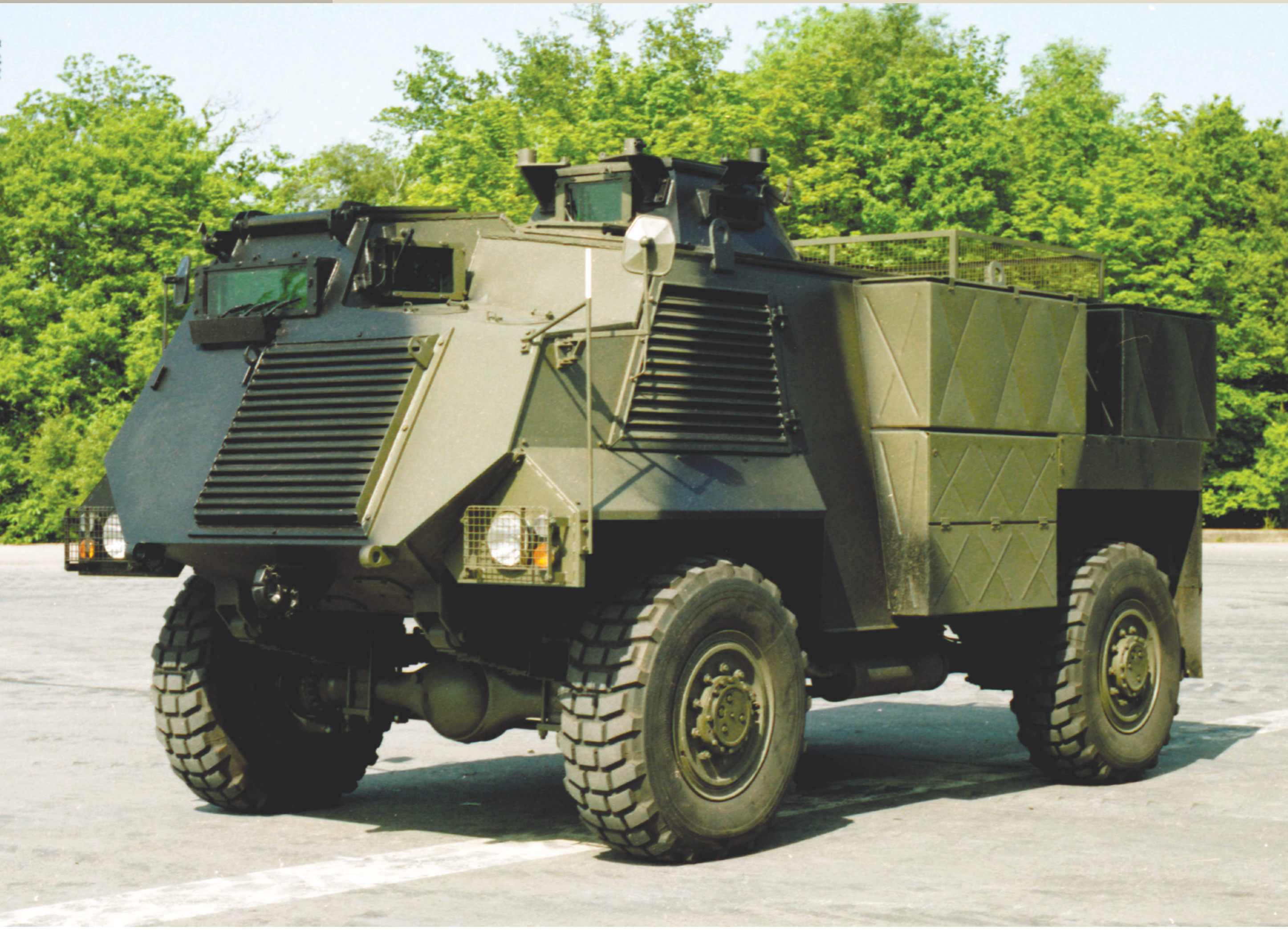
SP70: 155MM SELF-PROPELLED HOWITZER

SP70 was a joint UK, West Germany and Italian project to develop a 155mm self-propelled howitzer. The workshare reflected the intended numbers to be procured which were: Germany 400, UK 221 and Italy 90. It was intended initially to replace the Abbot in British Army service and then the M109. West Germany was responsible for the hull, the UK the turret systems and Italy the auxiliary power unit and various auxiliary systems. The gun was based on that developed under the joint FH-70 155mm project and the German-developed automotives were based largely on Leopard components. As Chertsey was focused on the development of 4030 and MBT80, the Royal Armaments Research and Development Establishment at Fort Halstead took the lead for the UK; however, Chertsey remained closely involved in the testing of the automotive and other systems. Development started in 1973 and five prototypes were completed by 1976. For a self-propelled gun SP70 was unusual in that the turret was centrally mounted rather than at the rear of the hull with rear access doors for replenishment. As a result, it was fitted with a complex ammunition handling system to transfer rounds into the turret. Although prototypes were built and tested the project was subject to delays, cost over-runs and reliability issues and so did not go into production. Abbot and M109 were later replaced in service by the AS90 self-propelled gun which was developed by Vickers Shipbuilding and Engineering Limited (VSEL) as a private venture vehicle but then modified for British Army use.

As discussed above the MICV-based SP gun was developed as an alternative to SP70 and a Chieftain-based vehicle was also considered. This would have been 9.5 tonnes lighter than the MBT, due to the lighter turret, and so mobility and reliability benefits were anticipated.



SP70 undertaking firing trials. (Crown Copyright MOD)



Saxon armoured transport vehicle being used for trials at the Longcross test track. (The Tank Museum, Bovington)

SAXON

Saxon was a wheeled armoured transport vehicle developed by GKN Sankey who used the designation AT105. AT105 was developed as a low-cost 4x4 vehicle based around the running gear of a Bedford M-Series truck. Protection was provided by 16mm steel armour plate which was proof against threats up to 7.62mm armour-piercing rounds and 155mm artillery fragments. Trials were carried out by Chertsey using a variety of threats to verify the protection levels, including the 7.62mm L1A1 SLR round and the US M1 Garand 0.3in. round, at ranges down to 7m. The V-shaped hull was designed to provide protection against mines.

Following trials with the Armoured Trials and Development Unit, Saxon entered service as a troop transport vehicle that provide significantly better protection when operating in rear areas than the usual Bedford trucks and was more suitable for transporting troops over long distances than the tracked FV432. The vehicle had a driver and commander and eight troops were carried over longer distances, although ten could be accommodated. Large external stowage bins were provided for their equipment. Although good for its intended role, which was to transport troops forward quickly and safely along roads and tracks, it performed less well when used off-road as its high centre of gravity made it liable to roll over. In addition to the basic troop carrier, GKN Sankey marketed police/internal security variants, a mortar carrier, an ambulance and a signals/command vehicle. A small turret with a machine gun could be fitted. Five hundred were procured for British Army use.

Basic characteristics of the troop carrier were:

Length: 5.17m
Width: 2.49m
Height: 2.63m
Weight (unladen): 8.64 tonnes
Payload: 2.03 tonnes
Engine: GM/Bedford Type 500 six-cylinder diesel rated at 110kW (147bhp)
Maximum speed: 96kph

Saxon entered British Army service in 1983 and was mainly deployed to Germany, but it was also used in Northern Ireland. In addition to the UK, 14 other nations used AT105, mostly for use by the police for internal security operations.

VICKERS MAIN BATTLE TANKS

As well as undertaking development and production work for the Chieftain and other vehicles for the British Army, Vickers developed a number of private venture vehicles some of which drew on design experience, technologies and sub-systems developed for British Army vehicles.

The Vickers Mark 1 was developed in response to a request from India for a vehicle that had similar firepower to Centurion but was lighter. The request was driven by a requirement for a vehicle to operate in the high mountainous areas along the north-eastern frontier to counter the threat from China. The resulting vehicle was very similar in looks and configuration to Centurion, with the same 105mm gun in a similar mounting and retaining an advanced stabilization and gun control system with a ranging machine gun. The armour, however, was thinner. The suspension was torsion bar, building on experience from the FV300 series. The power pack was the L60 coupled to the TN12 transmission as per Chieftain; however, the engine was derated to 535hp and in the much lighter vehicle proved to be much more reliable. The prototype was completed in 1963 in the UK but a manufacturing facility was set up in India with production there starting in 1965. Ninety vehicles went into service with the Indian Army as the Vijayanta (Victorious) tank. It also went into service with the Kuwait Army.

Key characteristics:

Length: Hull 7.92m, gun forward 9.73m
Height to turret roof: 2.44m
Width: 3.168m
Weight: Combat 38.6 tonnes, unladen 36.0 tonnes
Ground pressure: 0.87kg/cm^2
Max road speed: 48kph

The Mark 2 was intended as an improved version of the Mark 1 with a revised turret structure giving enhanced protection. The Mark 3 was a further improved version of which 136 entered service with the Nigerian Army. It was also procured by the Kenyan Army. Improvements on the Mark 3 included a redesigned cast turret that provided increased protection, a 720hp General Motors 12v1T diesel engine and an improved fire control system with a laser rangefinder. Bridge layer and recovery variants of the Mark 3 were developed.

The Mark 4 was developed in 1977 and incorporated Chobham armour. As it was a radical advance on the Mark 3 it was called the Valiant. It never went into service but the turret was further evolved into the Vickers Universal Turret. As well as the use of Chobham armour the

Valiant exploited other technologies from the British armoured vehicle research and development activities, including the use of an aluminium hull and Rolls-Royce CV12 engine. The turret was designed to be fitted with either the UK L11 120mm rifled gun or the German 120mm smoothbore.

The Vickers Mark 7 mounted the universal turret on a Leopard 2 hull. Army crews from the Armoured Trials and Development Unit supported the demonstration of the Mark 7 to Egypt from August to October 1985 following training on the vehicle in June and July 1985. Although it never went into production the turret systems were carried across to the design of Challenger 2.

The Vickers turrets did form the basis of turrets designed for the Osorio tanks developed by the Brazilian company Engesa. Engesa had developed the Cascavel reconnaissance vehicle and Urutu amphibious carrier, 2,767 of which were sold to 20 different countries. Engesa wanted to follow up the success of wheeled products by starting the development of a Main Battle Tank; however, they lacked experience in tank development and so eventually collaborated with Vickers who took over prime responsibility for the turrets. The plan was to develop two turrets that could be fitted to a common hull. The simpler ‘T1’ turret was proposed for use by the Brazilian Army and the more advanced ‘T2’ turret was aimed at potential order from Saudi Arabia for 316 vehicles. The T1 turret was based on the Valiant turret and the prototype, armed with a 105mm rifled gun, was completed in 1985. The T2 turret was based on the Mark 7 turret and was completed in 1985. T2 was armed with the French 120mm smoothbore gun. Vehicles with the T1 and T2 turrets were demonstrated in Saudi Arabia in 1985 and 1987 respectively. No orders were received from either the Brazilian Army or Saudi Arabia and Engesa eventually went into receivership.

APPENDICES

APPENDIX A: LIST OF FV NUMBERS

The following is a list of 'FV' numbers for vehicles and equipment and so represents a comprehensive list of the projects that Chertsey was involved with.

FV101: Tortoise (six built at the end of World War II but not brought into service)[18]
FV102: Self-propelled anti-tank vehicle[19]
FV101: Scorpion light tank with 76mm gun
FV102: Striker with Swingfire missile launchers
FV103: Spartan APC
FV104: Samaritan ambulance
FV105: Sultan ACV
FV106: Samson ARV
FV107: Scimitar light tank with 30mm RARDEN cannon
FV109: Unconfirmed but some sources give this as FV432 replacement
FV120: Unconfirmed but some sources give this as Spartan with Milan compact turret
FV180: CET
FV200: Series of variants of proposed Universal Tank
FV201: Universal Tank (A45) 17-pdr gun (later 20-pdr)
FV202: Proposed AVRE(T) with 6.5in. demolition charge launcher
FV203: Proposed AVRE(L); Ark version also capable of mine laying
FV204: Universal flail
FV205: SP medium anti-tank vehicle
FV206: SP medium artillery
FV207: SP heavy artillery
FV208: Universal bridge layer
FV209: Universal ARV
FV210: Heavy artillery tractor
FV211: Medium artillery tractor
FV212: Assault personnel carrier
FV213: BARV
FV214: Conqueror heavy tank
FV215: Proposed 183mm gun on Conqueror heavy tank chassis
FV216: Flail tank
FV217: SP 120mm anti-tank
FV219: Conqueror ARV Mk 1

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[18] The Tortoise is referred to as FV101 in a Director Royal Armoured Corps Liaison letter number 37 of 1948.

[19] Listed in record of the RAC Conference 22–29 October 1947.

FV221: Caernarvon medium gun tank; Centurion Mk 3 turret on a Conqueror hull[20]
FV222: Conqueror ARV Mk 2
FV223: Ark
FV301: 21-ton tank with 77mm gun (based on A46)
FV302: GPO/CPO Command vehicle
FV303: 20-pdr self-propelled gun
FV304: 25-pdr self-propelled gun
FV305: 5.5in. self-propelled gun
FV306: Light ARV
FV307: Radar vehicle
FV308: Field artillery tractor
FV309: RA section vehicle
FV310: APC
FV311: Armoured load carrier
FV400: 17.6-ton tank with 77mm gun
FV401: Cambridge series of carriers
FV402: Armoured OP vehicle
FV403: Tractor light anti-tank
FV404: Charging vehicle
FV405: Light gun carrier
FV406: Command vehicle
FV407: Air cooperation signals vehicle
FV408: Armour ambulance
FV409: Gun position officer vehicle
FV420: Tracked load carrier, unarmoured
FV421: Cargo carrier, 5-ton capacity
FV421: 'Badger', a School of Tank Technology design study for a light mobile anti-tank weapon that pre-dated the FV420 programme
FV422: Personnel carrier
FV423: Command vehicle
FV424: Royal Engineers variant
FV425: REME variant
FV426: Carrier tracked launcher, Orange William HESH AT missile
FV431: Armoured load carrier (Trident)
FV432: APC (Trojan)
FV433: 105mm Field Artillery self-propelled (Abbot)
FV434: Carrier maintenance full track (armoured repair variant of FV432)
FV435: Original allocation to a mine-laying version – study only
FV435: Wavell communications vehicle
FV436: SP motor locating radar (FV432 variant with Green Archer radar)
FV437: Pathfinder vehicle based on FV432 with snorkel gear
FV438: FV432 variant Swingfire missiles
FV439: Signals version of FV432
FV500: Series of amphibious vehicles[21]
FV501: Amphibious load carrier 4-ton general service (GS) (Neptune)
FV502: Amphibious flamethrower Sea Serpent (prototype only)
FV503: Amphibious ARV (Sealion)
FV510: Warrior mechanised combat vehicle
FV511: Warrior infantry command vehicle
FV512: Warrior repair vehicle
FV513: Warrior recovery vehicle
FV514: Warrior OP vehicle
FV515: Warrior battery command

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[20] This number was originally intended for a new medium gun tank to replace Centurion.

[21] Development of the Neptune 4-ton Amphibian started in May 1944 and was intended as alternative to the US LVT Buffalo. Two thousand were ordered but few delivered before the end of World War II. Designated FV501 these vehicles went out of service when it was demonstrated that the FV400 series could be provided with an amphibious capability using a wading screen.

vehicle
FV520: Warrior mechanized combat vehicle – capability sustainment version with 40mm cannon
FV521: Warrior infantry command vehicle – capability sustainment version with 40mm cannon
FV522: Warrior repair – capability sustainment version
FV523: Warrior recovery – capability sustainment version
FV524: Warrior OP vehicle – capability sustainment version
FV601: Saladin
FV602: Command vehicle – cancelled in 1949 with the role later covered by FV604
FV603: Saracen
FV604: Saracen Regimental Command Post (CP)
FV605: Proposed purpose-built ambulance variant of FV603
FV610: Saracen Royal Artillery CP (high roof)
FV611: Saracen ambulance
FV621: Alvis Stalwart Mk 1
FV622: Truck, cargo high-mobility load carrier, Alvis Stalwart Mk 2 6x6
FV623: Truck, cargo high-mobility load carrier, Alvis Stalwart Mk 2 6x6, Artillery Limber
FV652: Truck, fire-fighting foam, Alvis Mk 6A 6x6
FV701(J): Scout car liaison, Ferret Mk 1
FV701(H): Scout car reconnaissance, Ferret Mk 2
FV703: Scout car reconnaissance/Ferret Mk 2/6 with Vigilant ATGW
FV704: Scout car liaison Ferret Mk 1/2
FV711: Scout car reconnaissance, Ferret Mk 4 (Daimler Ferret 4x4 big-wheeled)
FV712: Scout car reconnaissance/GW, Mk 5 (Daimler Ferret 4x4 big-wheeled)
FV721: Combat Vehicle Reconnaissance (wheeled) Fox
FV800: Series of half-tracks based on the Bedford Traclat
FV801: ¾-track tractor heavy artillery
FV802: ¾-track tractor medium artillery
FV803: ¾-track ACV
FV901: Medium ¾-track load carrier GS
FV902: Medium ¾-track slave vehicle
FV903: Medium ¾-track tractor field artillery
FV904: Medium ¾-track tractor anti-tank artillery
FV905: Medium ¾-track radar vehicle
FV906: Medium ¾-track armoured load carrier GS
FV907: Medium ¾-track Motor Battalion Section vehicle
FV908: Medium ¾-track light-armoured ambulance
FV1001: Heavy 6x6 tractor for full trailers[22]
FV1002: 6x6 tractor for heavy and medium artillery
FV1003: Heavy 6x6 tractor for semi-trailers
FV1004: Heavy 6x6 breakdown vehicle
FV1005: Heavy 6x6 crane lorry
FV1066: Proposed low-cost tank with 20-pdr gun (superseded by FV4101)
FV1101: Truck 10-ton 6x6 AEC

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[22] The FV1000 series is mentioned in the record of the RAC Conference of October 1947 where it states it will be the ‘biggest wheeled vehicle which has been seen in this country’ and is said to have reached wooden mock-up stage.

FV1102: Truck 10-ton 6x6 for semi-trailer signals bodies
FV1103: Leyland Martian medium artillery tractor, 10-ton, 6x6 Leyland
FV1110: Truck 10-ton 6x6 GS
FV1111: Truck 10-ton 6x6 tanker 2,500 gallons
FV1112: Truck 10-ton 6x6 road repair vehicle
FV1113: Truck 10-ton 6x6 armoured signals vehicle
FV1114: Truck 10-ton 6x6 crane and excavator vehicle
FV1115: Truck 10-ton 6x6 tipper
FV1116: Truck 10-ton 6x6 self-propelled anti-aircraft gun mounting
FV1117: Truck 10-ton 6x6 meat Lorry
FV1118: Truck 10-ton 6x6 workshop and machinery
FV1119: Recovery vehicle wheeled – heavy (Leyland 10-ton 6x6)
FV1121: Truck cargo dropside (Leyland 10-ton 6x6)
FV1122: Tractor wheeled GS for 8in. howitzer (Leyland 10-ton 6x6)
FV1201: Tractor 30-ton 6x6 Heavy Artillery
FV1205: Tractor 30-ton 6x6 Recovery Super Heavy
FV1206: Tractor 30-ton 6x6 for semi-trailer – cross country
FV1207: Tractor 30-ton 6x4 for semi-trailer – road
FV1300: Proposed series of 3-ton 6x6 trucks; outline design only
FV1301: Truck 3-ton 6x6 long chassis GS
FV1302: Truck 3-ton 6x6 radar vehicle
FV1303: Truck 3-ton 6x6 armoured staff vehicle
FV1304: Truck 3-ton 6x6 technical vehicles; signals and medical
FV1305: Truck 3-ton 6x6 searchlight vehicle
FV1306: Truck 3-ton 6x6 petrol tanker 800 gallons
FV1308: Truck 3-ton 6x6 breakdown vehicle
FV1309: Truck 3-ton 6x6 water tanker 600 gallons
FV1310: Truck 3-ton 6x6 winch and tipper truck
FV1312: Truck 3-ton 6x6 tractor field artillery long wheel base
FV1313: Truck 3-ton 6x6 tractor field artillery short wheel base
FV1315: Truck 3-ton 6x6 heavy ambulance
FV1316: Truck 3-ton 6x6 fire engine and tender
FV1601: Truck 1-ton 4x4 GS, Humber
FV1602 (A): Truck 1-ton 4x4 Cargo Humber; originally designation for a proposed light artillery tractor
FV1602(B): As FV1602(A) but fitted with a winch
FV1603: Truck 1-ton 4x4 light ambulance (proposal only)
FV1604: Corporal missile command wireless vehicle; originally designation for a proposed signal variant
FV1605: Truck 1-ton 4x4 200-gallon water tanker (proposal only)
FV1606: Truck 1-ton 4x4 breakdown vehicle (proposal only)
FV1607: Truck 1-ton 4x4 staff car

FV1608: Truck 1-ton 4x4 with soft top cab
FV1609: Pig Hardtop Mk 1 prototype – later converted to FV1611
FV1611: Truck 1-ton, armoured 4x4 Humber – fitted for troop transport
FV1612: Truck 1-ton, armoured 4x4 Humber – fitted as radio truck
FV1613: Truck 1-ton, armoured 4x4 Humber – fitted as ambulance
FV1620: Humber Hornet truck 1 ton, Air-portable launcher, 4x4 Hornet (Malkara launcher)
FV1621: Truck 1-ton, missile resupply vehicle
FV1622: Truck 1-ton, missile resupply vehicle
FV1801A: Truck, ¼-ton, CT[23], 4x4 Austin, Mk 1 (Austin Champ)
FV1802: Truck, utility, CT, 4x4, Austin (prototypes only)
FV1901: Wheeled amphibian
FV2003: Motorcycle GS – 350cc BSA
FV2101: 3-ton 4x4 tractor
FV2191: 3-ton 4x4 tractor RAF
FV2201: Tractor flight deck
FV2241: Tractor for towing heavy aircraft
FV2301: Trailer, ½ ton, two wheel
FV2301(L): Trailer, ½ ton, compressor
FV2301(N): Trailer, ½-ton 100-gallon tank
FV2308: Malkara missile test trailer
FV2308(A): Water purification unit, trailer mounted
FV2361: Trailer, cargo (¾ ton)
FV2362: Trailer, tanker, water, ¾ ton, 455l
FV2365: Welding set lightweight trailer mounted
FV2368: Trailer 10Kw 400Hz generator ¾ ton
FV2401A: Trailer, cargo, 1 ton (two wheel)
FV2401B: Trailer, water, 1 ton, 200 gallon
FV2401R: Generating set diesel engine 10kVA trailer mounted 1 ton
FV2401T: Air conditioner trailer mounted (No.54 Mk 2, 1 ton)
FV4211: Trailer, 1-ton missile resupply
FV2412: Trailer, 1-ton cargo (specialist)
FV2413: Trailer, 1-ton flat platform (specialist)
FV2420: Trailer Class 16, air-portable bridge (1 ton)
FV2425: Trailer 1-ton FA radar No.2 Mk 13
FV2501(A): Trailer, cargo, 2 ton, four wheel
FV2501(P): Trailer, 2-ton four-wheel signals technical body
FV2502: Trailer, cargo, 2 ton
FV2502(R): Trailer, 2-ton four-wheel laboratory pathology and hygiene
FV2502(U): Trailer, 2-ton four-wheel binned store
FV2502(V): Trailer, 2-ton four-wheel commander's caravan
FV2504: Photographic film processing hand trailer mounted (2 ton, air-portable)
FV2505: Trailer, flat platform, 2 ton
FV2508: Trailer, low platform earth moving ancillaries
FV2601: Trailer, 5-ton four-wheel cargo
FV2622: Trailer, 4-ton four-wheel motor tug Mark 6
FV2623: Trailer, 4-ton four-wheel motor tug Mark 7

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[23] CombaT.

FV2641: Trailer, 10-ton power vehicle for Red Maid
FV2691: Trailer, dummy axle recovery ¼ ton
FV2701: Trailer, 10 ton, four wheel
FV2721a: Trailer, Centurion AVRE
FV2801: Trailer, 10 ton, eight wheel
FV2821(A): Trailer, 5-ton workshop – for Air Ministry
FV2821(B): Trailer, 5-ton photographic library and plotting – for Air Ministry
FV2823(A): Trailer, 4-ton motor tug
FV2824: Equipment Radar, trailer mounted AA No.10 7.5 ton
FV2826: Trailer Antenna, 5 ton
FV2827: Equipment Radar, trailer mounted, 5 ton
FV2828: Equipment Radar, trailer mounted, 5 ton
FV2829: Trailer, transporter container body (Bloodhound LCP 5 ton)
FV2842: Trailer, Class 60 MGB, 3 ton
FV2901: Trailer, 15 ton, six wheel
FV3001: Trailer, 20-ton four-wheel semi-trailer
FV3005: Semi-trailer, 60-ton Tank Transporter (road)
FV3011: Semi-trailer, 50 ton – used with Thornycroft Antar tractor unit
FV3101: semi-trailer, 20-ton eight-wheel
FV3201: Trailer, 30 ton, eight wheel
FV3221: Trailer, recovery (10 ton)
FV3301: Semi-trailer, 60-ton tank transporter
FV3401: Trailer, 3-ton two-wheel special
FV3501: Trailer, 10-ton low loader – for Air Ministry (originally designated for 6-ton four-wheel trailer special)
FV3502: Trailer, 10-ton decompression chamber – for Air Ministry
FV3504 Trailer, 10-ton parachute drying
FV3506(A): Trailer, 10-ton parachute servicing
FV3541: Semi-trailer, 30 ton
FV3561: Trailer, dummy axle recovery, 10/30 ton
FV3572: MBT80 ARV
FV3601: Trailer, tank transporter No.1, 50 ton (originally designated for AVRE trailer)
FV3621: Trailer, 20-ton low loader
FV3701: Trailer, two-wheeled flamethrower – to be used with FV201
FV3702: Trailer, two-wheeled flamethrower – later system to be used with FV201
FV3705: Trailer, mine clearance equipment Giant Viper
FV3751: Centurion mono-trailer
FV3801: Gun tractor, Centurion components
FV3802: 25-pdr SP gun, Centurion components
FV3803: Command Post vehicle, Centurion components
FV3804: Ammunition vehicle, Centurion components
FV3805: 5.5in. SP guns (two prototypes)
FV3806: 7.2in. SP gun, Centurion components (proposal only)
FV3807: 120mm SP anti-tank gun (proposal only)
FV3808: SP gun (proposal only)
FV3809: 155mm SP gun (proposal only)
FV3901: Churchill Linked Ark
FV3902: Churchill VII Flail, ‘TOAD’
FV3903: Churchill VII AVRE Tank infantry dozer

FV3904: Churchill VII APC (Kangaroo)
FV4001: Centurion mine clearer
FV4002: Centurion Mk 5 bridge layer
FV4003: Centurion Mk 5 AVRE 165
FV4004: Conway tank destroyer with 120mm gun (prototype)
FV4005: Heavy self-propelled anti-tank gun, 180mm (prototype)
FV4006: Centurion ARV Mk 2
FV4007: Centurion Mk 1, 2, 3, 4, 7
FV4008: Centurion DD
FV4009: Tank, medium (not used)
FV4010: Tank destroyer, Centurion-based Medium Orange William or Malkara missile launcher
FV4011: Centurion Mk 5
FV4012: Centurion Mk 7/1, 7/2, 8, 8/1, 8/2
FV4013: Centurion Mk 1 ARV
FV4014: Tank, medium (not used)
FV4015: Centurion Mk 9, 9/1, 9/2 10
FV4016: Centurion Ark bridge layer
FV4017: Centurion Mk 10, 11, 12, 13
FV4018: Centurion BARV
FV4019: Gun tank modified to carry flamethrower, development work only (hence the number was re-used)
FV4019: Centurion Mk 5 with bulldozer blade from FV4003
FV4027: Chieftain ARV(P) with crane; for Iran
FV4028: Chieftain ARV(P) with crane and CV12 engine
FV4030/1: Chieftain developed for Iran; for Iran
FV4030/2: Shir 1, re-engined Chieftain for Iran; renamed Khalid for supply to Jordan
FV4030/3: Shir 2, Chobham-armoured protected tank being developed for Iran
FV4030/4: Challenger 1
FV4101: Cromwell Heavy AT Gun Charioteer
FV4201: Chieftain tank
FV4202: '40-ton Centurion' 105mm gun Chieftain predecessor
FV4203: Chieftain armoured engineer vehicle (winch) – AEV(W) (a number were re-used for AVRE)
FV4203: Centurion AVRE – with 105mm gun – modified gun tank
FV4203: Chieftain AVRE – reworked gun tanks
FV4204: Chieftain ARV Mk 5 and ARRV
FV4205: Chieftain AVLB bridge layer
FV4207: Chieftain armoured engineer vehicle (gun) – AEV(G)
FV4211: Experimental tank – world's first tank fitted with Chobham armour
FV4222: Possible number for a UK version of 4030/3
FV4333: Stormer APC
FV4401: Contentious
FV4501: Armoured mine clearer
FV4601: MBT-80
FV11001: Tractor, 10-ton 6x4 GS, AEC Militant Mk 2
FV11002: Tractor, 10-ton 6x6 GS, AEC Militant Mk 2
FV11003: Truck, crane bridging 6x6, AEC Militant
FV11005: Truck, end-tipper 6x6, AEC Militant
FV11009: Truck, fuel tanker 2,500-gallon 6x6, AEC Militant
FV11018: Truck, cargo 10-ton 6x6 GS,

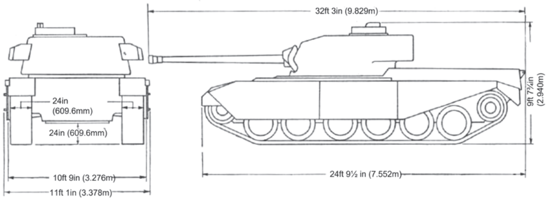
AEC Militant Mk 1
FV11010: Tractor, 10-ton 6x6 GS, AEC Militant
FV11021: BV202E Articulated Sno-Cat
FV11044: Recovery vehicle wheeled medium (6x6 AEC Mk 3)
FV11047: Truck, cargo 10-ton 6x6 GS, AEC Militant Mk 3
FV11061: ACV, heavy, AEC 10-ton 6x6
FV11081: Truck, missile transporter (AEC 10 ton, 4x2)
FV11101: Truck, 10-ton (Albion) cargo
FV11102: Truck, 10-ton (Albion) workshop
FV11103: Truck, 10-ton 6x4 (Leyland) for semi-trailer – for Air Ministry
FV11105: Truck, 10-ton 6x4 GS (Albion) tipper (three-way)
FV11203: Truck, 10-ton 6x4 GS (Leyland) for semi-trailer – for Air Ministry
FV11204: Truck, 10-ton 6x4 GS (Leyland) tipper – for Air Ministry
FV11205: Truck, 10-ton 6x4 GS (Leyland) cargo
FV11301: Tractor, 10-ton 6x6 GS (Scammell) recovery
FV11401 Tractor, 10-ton 6x4 GS (Thornycroft) for semi-trailer
FV11501: Truck, 10-ton Fire 6x4 tender foam (Douglas)
FV11502: Truck, 10-ton Fire 6x4 tender water (Douglas)
FV12002: Tractor, 30-ton 6x4 GS, Thornycroft Antar Mk 2
FV12003: Tractor, 30-ton 6x4 GS, Thornycroft Antar (ballast body)
FV12004: Tractor, wheeled semi-trailer (30-ton 6x4 GS, Thornycroft Antar Mk 3)
FV12101: Tractor, 20-ton 6x6 GS, Scammell
FV12102: Tractor, wheeled semi-trailer (Scammell 20 ton, 6x6)
FV12105: Tractor, wheeled GS (Scammell 20 ton, 6x6)
FV12201: Tractor, 20-ton 6x4 GS, Diamond T
FV12381: Truck tanker, fuel, servicing aircraft; 2,200-gallon, air-portable AEC Mercury 4x2
FV13001: Truck, 3-ton 4x4 GS (Austin) cargo
FV13007: Parachute transporter, 4x4 GS Austin (prototype only)
FV13101: Truck, 3-ton 4x4 GS, Bedford
FV13111: Truck, end-tipper 4-ton 4x4, Bedford SWB
FV13112: Truck, cargo dropside, Bedford 4 ton, 4x4
FV13113: Automotive repair shop, truck mounted, Bedford 3 ton, 4x4
FV13115: Recovery vehicle wheeled light, Bedford 3 ton, 4x4
FV13120: Truck, tanker, water, 3 ton, 4x4, 600 gallon, Bedford RL
FV13142: Truck, cargo, 4 ton 4x4, air-portable, Bedford
FV13149: Truck, tanker, fuel (dispensing), 4 ton, 4x4, 600 gallon, Bedford RL
FV13165: Truck, mobile dental clinic, 4 ton, 4x4, Bedford
FV13197A: Truck, 3 ton, domestic water, aircraft replenishment (RAF)
FV13198A: Motor coach large with ambulance role, Bedford 4x2
FV13199: Truck tanker, fuel, servicing aircraft, 1,000 gallon, Bedford 3 ton, 4x2

FV13201: Truck, 3-ton 4x4 GS, Commer
FV13218: Truck, 3-ton 4x4 GS, Commer Recovery
FV13219: Truck, end-tipper, 3 ton, 4x4, Commer
FV13206: Truck, mobile workshop, 3 ton, 4x4, Commer
FV13208: Truck, 3-ton GS, Commer Instrument Repair
FV13303: Truck, 3-ton 4x4 GS Ford
FV13801/13801: Truck, cargo, Bedford MK 4 ton, 4x4
FV13803/13804: Truck, cargo with winch, Bedford MK 4 ton, 4x4
FV14101: Truck/tractor, 5-ton GS, Thornycroft
FV16001: Truck, cargo 1-ton 4x4 GS, Austin
FV16002: Truck, cargo 1-ton 4x4 GS, Austin FFW
FV16003: Truck, 1-ton 4x4 wireless, Austin
FV16008: Truck, 1-ton 4x4 200 water tanker, Austin
FV16100: Truck, 1-ton 4x4, Morris
FV18001: ¼-ton 4x4 GS Land Rover
FV18005: Truck, ¾-ton 4x4 ambulance Land Rover Series
FV18008: Truck, ¾-ton 4x4 ambulance Land Rover Series I
FV18031: Truck GS, fitted for radio, Rover 10, ¼ ton, 4x4
FV18032: Truck GS, Rover 10, ¼ ton, 4x4
FV18032: Truck GS line layer, Rover 10, ¼ ton, 4x4
FV18044: Truck, ¾-ton 4x4 ambulance Land Rover Series 2
FV18047: Truck, fire-fighting airfield crash rescue, Rover ¾ ton, 4x4
FV18061: Scottern Bushmaster Mk II powered axle trailer, 1 ton
FV18061: Truck GS, Rover 11, ¾ ton, 4x4
FV18062: Truck GS fitted for radio, Rover 11, ¾ ton, 4x4
FV18067: Ambulance two/four stretcher, Rover 11, ¾ ton, 4x4
FV23225: Truck, light recovery, 4 ton, 4x4, Bedford
FV30011: Semi-trailer, 50 ton, tank transporter

APPENDIX B: CENTURION DATA

MARK 3 DATA

Data from User Handbook
Most data applies to Mark 5 and 6



Centurion Mark 3 dimension diagram from User Handbook. (Crown Copyright MOD)

Crew: Four: commander, driver, gunner, operator
Weight: Laden 50,803 ton
Ground pressure: 0.8999kg/cm^2
Power-to-weight-ratio: 13.0bhp/ton
Bridge classification: 60

DIMENSIONS:
Length: Hull 7.556m
Gun in forward position: 9.829m
Gun in travelling position: 8.61m
Height: Cupola hatch vertical: 3.455m
Cupola hatch closed: 2.94m
Width: With side plates in position: 3.378m
With side plates removed: 3.276m
Ground Clearance: 0.508m

MAIN ARMAMENT:
Mark 3 and 5: 20-pdr Tk Mark 1
Mark 6: 105mm Tk L7A1
Smoke Granade Launchers: No.80 system

VISION AND OPTICS SYSTEMS:
Commander's cupola:
Early vehicles: No.2 Mark 1 with nine episcopes
Later vehicles: No.2 Mark 2 with eight episcopes No.7 Mark 1 and main sight AFV No.2 x10 mag
Gunner's sight: sighting periscope AFV No.1

MAIN ENGINE:
Type: Meteor Mk 4B
Bore: 5.4in. (137.17mm)
Stroke: 6in. (152.4mm)
Compression ratio: 7 to 1
Number of cylinders:12
Capacity: 1,649cu in. (27 litres)
Max bhp (gross): 650 at 2,550rpm
Maximum governed speed: 2,550rpm
Clutch: Borg and Beck – triple plate
Gear box: Merritt Brown Z51
Suspension: Horstmann
Track: Single pin
Width: 609.6mm
Pitch: 139.7mm
Number of shoes per track (when new): 108

PERFORMANCE:
Maximum road speed: 34.6kph
Vertical obstacle: 0.914m
Maximum gradient: 30–35 degrees
Trench crossing: 3.353m
Shallow fording: 1.448m
Deep fording: Turret top

SPEED IN EACH GEAR AT 2,550rpm:
5th gear (top): 34.6kph
4th gear: 24.14kph
3rd gear: 16.254kph

2nd gear: 10.141kph
1st gear: 4.032kph
Low reverse: 2.027kph
High reverse: 11.908kph

CAPACITIES:
Fuel tanks: 545.5l

RANGE:
Cross country: 52.3km (at 0.095km/l)
Road work: 100.53km (at 0.184km/l)

MARKS 7, 8, 9 AND 10 DATA

Data from User Handbook

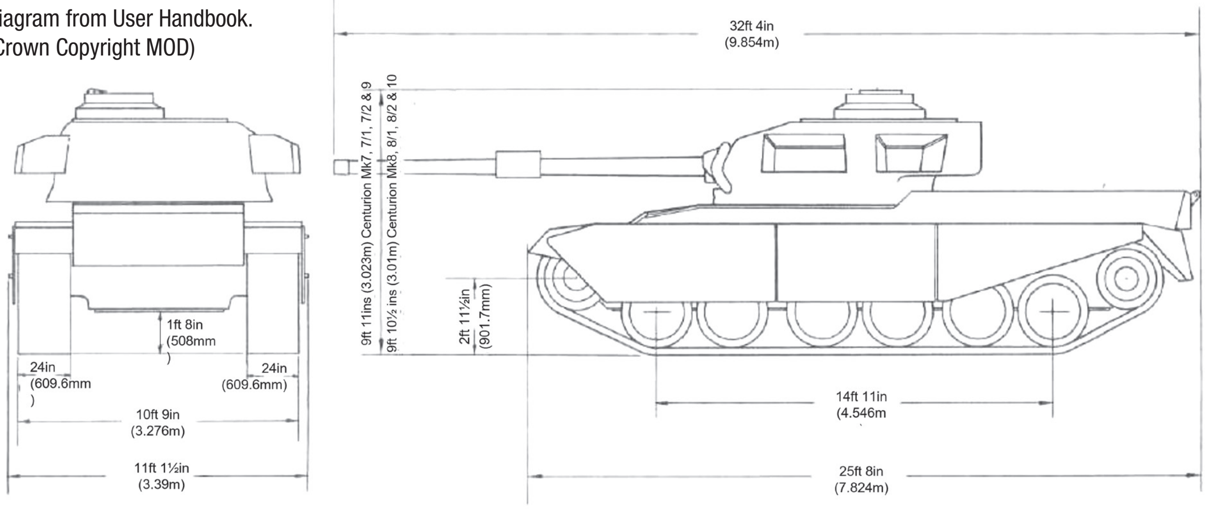
Crew: Four: commander, driver, gunner, operator
Weight: Unladen, 48,060 ton; Laden, 51,616 ton
Ground pressure: 0.928kg/cm^2
Power-to-weight ratio: 12.5bhp/ton
Bridge classification: 60

DIMENSIONS:
Length: Hull 7.824 m
Gun in forward position: 9.854m
Gun in travelling position: 8.534m
Height:
  Cupola hatch vertical: Mk 7, 7/1, 7/2 and 9: 3.455m
  Mk 8, 8/1, 8/2 and 10: 3.226m
  Cupola hatch closed: Mk 7, 7/1, 7/2 and 9: 3.023 m
  Mk 8, 8/1, 8/2 and 10: 3.01m
Width: With side plates in position: 3.39m
With side plates removed: 3.276m
Ground clearance: 0.508m

MAIN ARMAMENT:
Mark 7: 20-pdr Tk Mark 1
Mark 8, 9 and 10: 105mm Tk L7A1
Smoke Grenade launchers: No.80 system

VISION AND OPTICS SYSTEMS:
Commander's cupola: Mark 7 and 9:
  Vision cupola No.6 Mark 1 with a single circular hatch. Eight episcopes, seven fixed (No.7 Mark 1) and one extensible (No.8 Mark 1), an AFV No.4
  Mark 1 or Mark 2 commander's sight and an AFV No.2 Mark 1 or Mark 1/1 periscopic binocular
  Mark 8 and 10: Contra-rotating vision

Centurion Mark 7–10 dimension diagram from User Handbook. (Crown Copyright MOD)


1ft 8in
(508mm
)
24in
(609.6mm
)
24in
(609.6mm)
10ft 9in
(3.276m)
11ft 1½in
(3.39m)
32ft 4in
(9.854m)
9ft 11ins (3.023m) Centurion Mk7, 7/1, 7/2 & 9
9ft 10½ ins (3.01m) Centurion Mk8, 8/1, 8/2 & 10
2ft 11½in
(901.7mm)
14ft 11in
(4.546m
25ft 8in
(7.824m)

cupola No.4 Mark 1 with two semi-circular hatches. Six episcopes (No.7 Mark 1), an AFV No.4 Mark 1 commander's sight and an AFV No.2 Mark 1 or Mark 1/1 periscopic binocular
Gunner: AFV No.10 Mark 1 or No.18 Mark 1 or Mark 2 x6 magnification sighting periscope
Loader/Operator: one No.28 Mark 1 periscope
Driver: two No.15 Mark 1 periscopes

MAIN ENGINE:
Type: Meteor Mk 4B or 4-B/1 V12
Bore: 5.4in. (137.17mm)
Stroke: 6in. (152.4mm)
Compression ratio: 7 to 1
Number of cylinders: 12
Capacity: 1,649cu in. (27 litres)
Max bhp (gross): 650 at 2,550rpm
Maximum governed speed: 2,550rpm
Clutch: Borg and Beck – triple plate
Gear Box: Merritt Brown Z51
Suspension: Horstmann

TRACK:
Width: 609.6mm
Pitch: 139.7mm
Number of shoes per track (when new): 108

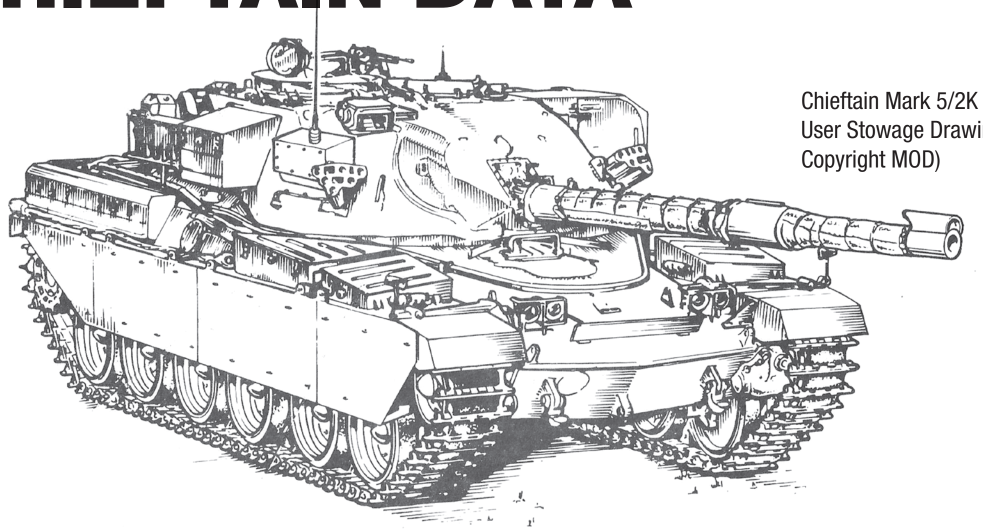
PERFORMANCE:
Maximum road speed: 34.6kph
Vertical obstacle: 0.914m
Maximum gradient: 30–35 degrees
Trench crossing: 3.353m
Shallow fording: 1.448m
Deep fording: Turret top

SPEED IN EACH GEAR AT 2,550rpm:
5th gear (top): 34.6kph
4th gear: 24.14kph
3rd gear: 16.254kph
2nd gear: 10.141kph
1st gear: 4.032kph
Low reverse: 2.027kph
High reverse: 11.908kph

CAPACITIES:
Fuel tanks: 1,036l
Right tank: 254.5l
Left tank: 782l

RANGE:
Cross country: 95.9km (at 0.095km/l)
Road work: 190km (at 0.184km/l)

APPENDIX C: CHIEFTAIN DATA



Chieftain Mark 5/2K diagram from User Stowage Drawings. (Crown Copyright MOD)

Crew: Four: commander, gunner, driver, loader

WEIGHT LADEN:

54.1 tonne: Mark 1, 2, 3 and 3/1
54.4 tonne: Mark 3/3
54.8 tonne: Mark 5 and 5P
55.8 tonne: Mark 5/3P and 12
55.7 tonne: Mark 5/2K and 13

WEIGHT UNLADEN:

51.46 tonne: Mark 1, 2, 3 and 3/1
51.76 tonne: Mark 3/3
52.0 tonne: Mark 5 and 5P
52.8 tonne: Mark 5/3P and 12
52.7 tonne: Mark 5/2K and 13

DIMENSIONS:

Hull length: 7,518mm: Mark 1, 2, 3, 3/1, 3/1, 5, 5P, 5-3P
7,655mm: Mark 5/2K, 12 and 13
Length gun forward:10,795mm: Mark 1, 2, 3, 3/1, 3/1, 5, 5P, 5-3P
10,823mm: Mark 5/2K, 12 and 13
Height to turret top: 2,641.6mm: Mark 1, 2, 3, 3/1, 3/1, 5 and 5P
2,436.0mm: Mark 5-3P, 5/2K, 12 and 13
Height to top of cupola: 2,870.2mm: Mark 1, 2, 3, 3/1, 3/1, 5 and 5P
2,802.0mm: Mark 5-3P, 5/2K and 13
2,828.0mm: Mark 12
Width including searchlight: 3,613.1mm: Mark 1 and 2
3,657.6mm: Mark 3, 3/1, 3/1 and 5
Ground clearance: 518mm: Mark 1, 2, 3, 3/1, 3/1, 5
498mm: Mark 5-3P, 5/2K and 13

MAIN ARMAMENT:

120mm L11 gun
Elevation: 20 degrees
Depression: -10 degrees

STOWED ROUNDS:

30 APDS, 34 HESH
(10APDS external): Mark 5, 5-P, 5-3P, 5/2K and 13

SECONDARY ARMAMENTS:

Coaxial machine gun: 7.62mm L8A1 GPMG
Commander's machine gun: None: Mark 1 7.62mm L37A1 GPMG
Ranging machine gun: 0.5in. Browning: Mark 1, 2, 3, 3/1, 5, 5P and 5-3P
Smoke launchers: Discharger, grenade, multi-barrel No.9 Mark 1, 2 off, five grenades per launcher

VISION AND OPTICS SYSTEMS:

Commander's cupola:
  Mark 1: Mark 1
  Mark 2: Mark 2
  No.15 Mark 2: Mark 3, 3/1 and 3/3
  No.15 Mark 3: Mark 5, 5-P, 5-3P and 5/2K
  No.15 Mark 6: Mark 13
Cupola main sight: No.5 Mark 2: Mark 1
  No.8 Mark 1: Mark 2
  No.37 Mark 2: Mark 3
  No.37 Mark 3: Mark 3/1, 3/3 and 5
  No.37 Mark 4: Mark 5-P, 5-3P and 5/2K
  No.84 Mark 2: Mark 13
Cupola periscopes: No.26 Mark 2 and
  No.27 Mark 2: Mark 1
  No.34 Mark 1: Mark 2
  No.40 Mark 1: Mark 3
  No.40 Mark 2: Mark 3/1, 3/3, 5, 5-P, 5-3P, 5/2K and 13
Collimator: No.6 Mark 1: Mark 1
  No.7 Mark 1: Mark 2, 3
Projector reticule image: No.10 Mark 1: Mark 3/1
  No.13 Mark 1: Mark 3/3, 5, 5-P and 5/2K
  No.12 Mark 1, Mark 3/3, 5 when LRF fitted
Gunner's periscope: No.32 Mark 1: Mark 1
  No.38 Mark 1: Mark 2, 3
  No.57 Mark 2: Mark 3/1
  No.59 Mark 1 or Sight LRF Periscope
  No.1 Mark 1: Mark 3/3, 5, 5-P, 5-3P
  TLS No.3 Mark 1: Mark 5/2K
  THL No.2 Mark 1: Mark 13
Gunner's telescope: No.26 Mark 1: Mark 1 and 2
  No.60 Mark 1: Mark 3, 3/1 and 3/3
  No.70 Mark 1: Mark 5P and 5-3P
  No.70 Mark 2: Mark 5
  No.80 Mark 1: Mark 5/2K and 13
Thermal Observation and Gunnery Sight (TOGS): Mark 11
Loader's periscope: No.30 Mark 1
Driver's periscope: No.36 Mark 1
Gun control equipment: FV/GCE No.7 Mark 4:
  FV/GCE No.7 Mark 5:
  FV/GCE No.10 Mark 1: Mark 13
Radios[24]: C42/B47: Mark 1, 2, 3, 3/1, 3/3 and 5
  VRQ301 and PRC351: Mark 5-P
  VRQ301: Mark 5-3P
  VRC353: Mark 5/2K and 13
Engine: L60 No.4 Mark 4a, 585hp: Mark 1
  L60 No.4 Mark 4a, 650hp: Mark 2
  L60 No.4 Mark 5a, 650hp: Mark 3
  L60 No.4 Mark 6a, 650hp: Mark 3/1 and 3/3
  L60 No.4 Mark 7a, 720hp: Mark 5

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[24] Operational vehicles were modified to be fitted with the Clansman radio when that entered service. Vehicles with a Clansman Harness had '(c)' after their Mark number.

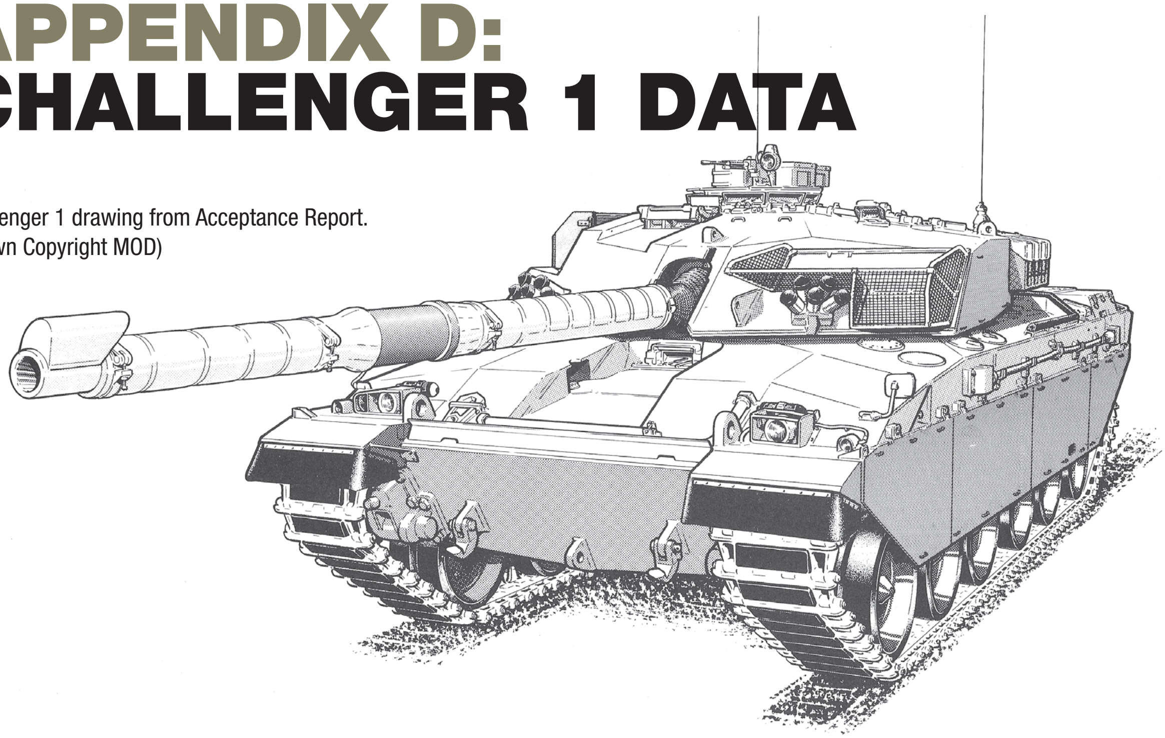
L60 No.4 Mark 8a, 750hp: Mark 5-P, 5-3P and 5/2K
L60 No.4 Mark 11a, 720hp: Mark 12 and 13
Axillary engine: H30 No.4 Mark 7a: Mark 1 and 2
H30 No.4 Mark 10a: Mark 3, 3/1, 3/3, 5, 5-P, 5-3P, 5/2K and 13
Transmission: TN12 Mark 3: Mark 1, 2, 3, 3/1, 3/3 and 5
TN12 Mark 4: Mark 5-P, 12 and 13
TN12 Mark 5: Mark 5-3P
TN12 Mark 7: Mark 5/2K

SUSPENSION:
Horizontal Helical (Horstmann), three bogies each side
Suspension Travel: Bump: 158.75mm
Rebound: 82.55mm
Track: Dry single pin, 609.6mm wide, 157mm pitch. Length of track on the ground: 4,775mm

PERFORMANCE:
Maximum speed: 40.7kph: Mark 1, 2, 3, 3/1, 3/3
43.5kph: Mark 5, 5-P, 5-3P, 5/2K, 12 and 13
Vertical obstacle: 901.7mm: Mark 1, 2, 3, 3/1, 3/3, 5 and 5-P
900.0mm: Mark 5-3P and 5/2K
950.0mm: Mark 13
Gradient: 35 degrees
Gap crossing: 3,150mm
Fording: 1067mm
Fuel capacity: 955l: Mark 1, 2, 3, 3/1, 3/3 and 12
950l: Mark 5, 5-3P and 5/2K
1,182l: Mark 5-P
NBC: Mark 1, 2: None
Mark 3 and 3/1: Collective protection system with No.2 NBC pack Mark 3/3: Collective protection system with No.6 Mark 1 NBC pack
Mark 5, 5-P, 5-3P, 5/2K, 12 and 13: Collective protection system with No.6 Mark 2 NBC pack

NOTES:
Mark 3/P MVEE Spec 543 is the same as the Mark 3 but without the laser range finder option
Mark 5-3P had improved mine protection
Mark13 had IR detection device as a standard fit
Sources of Information: Mark 1 and 2: FVRDE Specification 9311
Mark 3: FVRDE Specification 9370
Mark 3/1: FVRDE Specification 9371
Mark 3/3: FVRDE Specification 9379
Mark 5: FVRDE Specification 9381
Mark 5-P: MVEE Specification 562
Mark 5-3P: MVEE Specification 690
Mark 5/2K: MVEE Specification 694
Mark 12: British Military Vehicles 1981. This is an MVEE publication and the only official reference found to the Mark 12
Mark 13: DGFVE Specification 324

APPENDIX D: CHALLENGER 1 DATA



Challenger 1 drawing from Acceptance Report.
(Crown Copyright MOD)

Data from the Acceptance Test Report.

Crew: Four: commander, gunner, driver, loader

WEIGHT:

Combat: 62 tonnes
Training: 60.9 tonnes
Shipping: 59.9 tonnes

DIMENSIONS:

Length: Hull: 8,327mm
Total, gun front: 11,560mm
Height: Turret roof: 2,500mm
Top of commander's sight: 2,950mm
Width: Over tracks: 3,120mm
Over skirt plates: 3,510mm
Ground clearance: 500mm

ARMAMENTS:

Main weapon: ORD BL102mm TK gun L11 A5
Ammunition stowage: 52, 32 APDS, 17 HESH, three smoke
Charge stowage: 42 bins containing one APDS or two HESH charges
Coax machine gun: 7.62mm L8A2
Commander's machine gun: 7.62mm L37A2
Gun and fire control system: FV/GCE No.11 Mark 3
Smoke launchers: Discharger grenade No.18 Mark 1

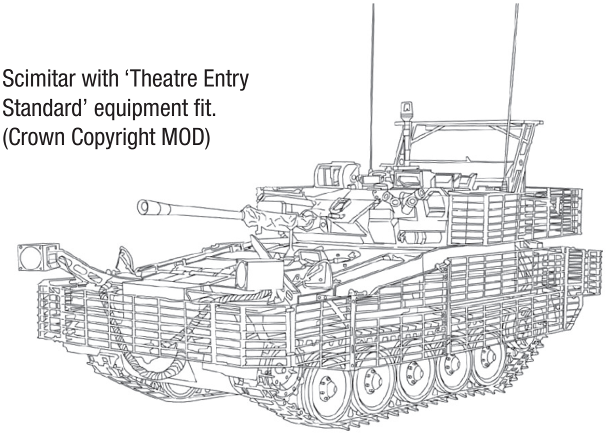
SIGHTING AND OPTICS SYSTEMS:

Commander's cupola: No.32 Mark 1
Commander's day sight: Sight periscope No.37 Mark 6
Commander's night sight: Sight periscope L5A1
Gunner's main sight: TLS No.10 Mark 1
Gunner's auxiliary sight: No.87 Mark 1
Thermal Observation and Gunnery Sight

(TOGS):
Loader's periscope: AV No.30 Mark 1
Driver's day sight: AV No.36 Mark 1
Driver's night sight: Image Intensifier L12A1
Communications: 2 x VRC 353
Engine: RR CV12 TCA 1,200 No.3 Mark 4a; 1,200BHP at 2,300rpm
Transmission: TN37 No.1 Mark 3
Auxiliary engine: Coventry Climax H30 No.4 Mark 18H
Suspension: Hydrogas, travel – 350mm bump, 100mm rebound
Track: Dry single pin, 650mm wide, 165mm pitch. Links per track: 92.
Length of track on the ground: 4,790mm

PERFORMANCE:
Speed: 56kph
Gradient: 58 per cent, Stop/Start 30 per cent
Side slope: 27 per cent
Vertical obstacle: 0.9m
Fording: 1.07m
Fuel: 1,727l, useable; 1,500l nominal
NBC: Collective protection system with No.6 Mark 2 NBC Pack vehicles 1-150, No.11 Mark 1 vehicle 151 onwards

APPENDIX E: CVR(T) DATA



Scimitar with 'Theatre Entry Standard' equipment fit. (Crown Copyright MOD)

Data from Alvis Data Sheets, Technical Specifications and Acceptance Reports

FV101 SCORPION/FV107 SCIMITAR

(Additional Information from RARDE Spec 9380)

Crew: Three: commander/loader, gunner/operator, driver
Weight: 7,938kg FV101, 7,750kg FV107 (Military Load Classification 9)
Ground pressure: 34.5N/m^2 FV101, 33.8N/m2 FV107
Air transportability: Two in C130

DIMENSIONS:

Length (gun forward): 4,788mm FV101, 4,985mm FV107
Height, to top commander's periscope: 2,102mm
Width, overall: 2,235mm FV101, 2,242 FV107
Width, over tracks: 2,134mm
Ground clearance: 356mm

ARMAMENT:

Main weapon:
  FV101: 76mm L23A1
  FV107: 30mm RARDEN L21A1
  Quick Firing (QF) Fixed Ammunition
Elevation: 35 degrees
Depression: 10 degrees
Stowed rounds: 40 FV101, 165 FV107 (later increased to 201)
Auxiliary armament: L37.A2 7.62mm machine gun
Smoke launchers: 2 off 3-barrel smoke launchers on turret

SIGHTING AND OPTICAL SYSTEMS:

Commander: Sight periscope AV No.71 Mark 1 x1/x10 day sight
  Six unity periscopes AV No.48 Mark 2
  One periscope AV No.43 Mark 3
Gunner: Sight periscope AV No.54 Mark 1 x10/x1 day sight
  Sight periscope AV, II, L3A1 x1.8/x6.5 passive night sight
  2x unity periscopes AV No.43 Mark 3
Driver: Wide-angle unity periscope AV No.44 Mark 2
Periscope: AV, II, L16A1 interchangeable passive night sight
BGTI: Commander additionally provided with a colour camera with 10x magnification and commander and gunner with thermal imager with wide and narrow Field Of View (FOV)
Communications: Clansman (later replaced with Bowman)

ENGINE:
Jaguar 4.2l J60 No.1 Mark 100B petrol six-cylinder I line
Capacity: 4.235l
Max power: 190bhp at 4,750rpm
Max torque: 345.8Nm at 3,500rpm
Generator: 140A at 28v
Transmission: TN15X Cross drive semi-automatic (seven forward and reverse gears) with integrated Merritt steering system
Suspension: Transverse torsion bars, 197mm bump, 132mm rebound
Tracks: Light steel rubber bushed, width 432mm, pitch 116mm. Links per side: 79. Length of track on the ground 2,490mm.

PERFORMANCE:
Maximum road speed: 80.5kph
Acceleration: 0–48.3kph (0–30mph) in 16s
Vertical obstacle: 500mm
Maximum gradient – stop/start: 45 per cent (24 degrees)
Angle of approach: 26 degrees
Angle of departure: 21.5 degrees
Fording, screen stowed: 1,067mm
Swimming: 6.44kph with tracks, 9.65kph with propeller kit and washboard
Fuel capacity: 423l
Range on roads: >644km
NBC: Collective protection system with No.5 Mark 1 NBC pack

FV103 SPARTAN

(Additional Information from MVEE Spec 536)

Crew: Seven: vehicle commander, driver, section commander and four passengers
Weight: 8,172kg (Military Load Classification 9)
Ground pressure: 33.8kN/m^2

DIMENSIONS:
Length: 4,930mm over body, 5,220mm total front mud flap to rear cable reel
Height, to top of machine gun: 2,290mm
Width, overall: 2,245mm
Width, over tracks: 2,145mm
Ground clearance: 356mm

ARMAMENT:
Cupola-mounted 7.62 GPMG L37A2
Smoke launchers: Two off four-barrelled smoke launchers

SIGHTING AND VISION SYSTEMS:
Commander's cupola No.16 Mark 1 with: x10 day sight No.62 Mark 1
eight unity periscopes No.42 Mark 1
x1.4 passive night sight L7A1
'Basic Element Periscope', appliqué sight that could be clamped to the side of the No.62 sight for use in low light conditions
Section Commander: Three unity periscopes No.43 Mark 3
Driver: Unity periscope No.44 Mark 2, interchangeable passive night sight L16A1
Crew compartment: Three x1 unity periscopes No.42 Mark 1 plus 1 vision block in rear door
Communications: Clansman

ENGINE:

Jaguar 4.2l J60 No.1 Mark 100B petrol six-cylinder
Capacity: 4.235l
Max power: 190bhp at 4750rpm
Max torque: 345.8Nm at 3500rpm
Generator: 140 amp 28V
Transmission: TN15X Cross drive semi-automatic, seven forward and reverse speeds
Suspension: Transverse torsion bars, 203mm bump, 102mm rebound
Tracks: Light steel rubber bushed, width 432mm, pitch 116mm. Links per side: 84.
Length of track on the ground 2,745mm

PERFORMANCE:

Maximum road speed: 80.5kph
Acceleration: 0–48.3kph (0–30mph) in 25s
Vertical obstacle: 500mm
Angle of approach: 26 degrees
Angle of departure: 21.5 degrees
Maximum gradient – stop/start: 45 per cent (24 degrees)
Fording, screen stowed: 1,067mm
Swimming: 6.44km/h with tracks, 9.65kph with propeller kit and washboard
Fuel capacity: 386l
Range on roads: >483km
NBC: Collective protection system with No.5 Mark 1 NBC pack

FV104 SAMARITAN

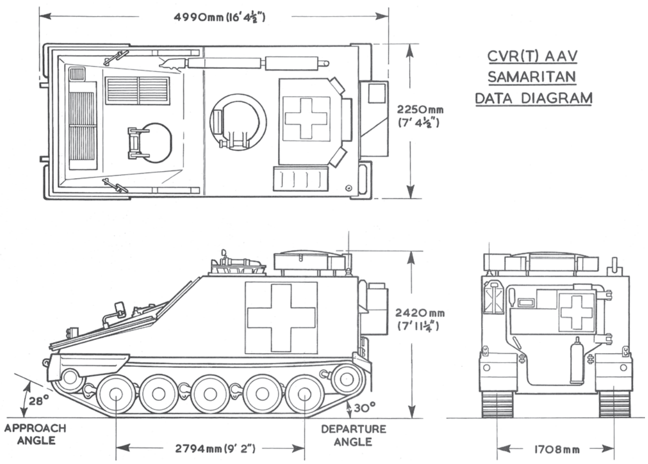
Crew: Three: driver, commander and medical orderly, plus four stretcher cases or five sitting cases
Weight: 8,664kg (Military Load Classification 9)
Ground pressure: 35.85kN/m^2

DIMENSIONS:

Length: 4,990mm
Height, to top of hull: 2,016mm
Height, to top of roof bin: 2,420mm
Width, overall: 2,250mm
Width, over tracks: 2,134mm
Ground clearance: 356mm
Armament: None
Smoke launchers: Two off four-barrelled smoke launchers

SIGHTING AND VISION SYSTEMS:

Commander's cupola: Five unity periscopes
Driver: Unity periscope, interchangeable passive night sight
Crew compartment: One vision block in rear door



Samaritan dimension diagram from Acceptance Report. (Crown Copyright MOD)

ENGINE:
Jaguar 4.2l J60 No.1 Mark 100B petrol six-cylinder
Max power: 190bhp at 4,750rpm
Max torque: 345.8Nm at 3,500rpm
Transmission: TN15X Cross drive semi-automatic
Suspension: Transverse torsion bars, 203mm bump, 102mm rebound
Tracks: Light steel rubber bushed, width 432mm, pitch 116mm

PERFORMANCE:
Maximum road speed: 72.5kph
Acceleration: 0–48.3kph (0–30 mph) in 25s
Vertical obstacle: 500mm
Angle of approach: 28 degrees
Angle of departure: 30 degrees
Maximum gradient – stop/start: 45 per cent (24 degrees)
Fording, screen stowed: 1,067mm
Swimming: 6.44kph with tracks, 9.65kph with propeller kit and washboard
Fuel capacity: 395l
Range on roads: >483km
NBC: Collective protection system with No.5 Mark 1 NBC pack

FV106 SAMSON

Crew: Three: commander, driver, recovery mechanic
Weight: 8,738kg (Military Load Classification 9)
Ground pressure: 35.85kN/m^2

DIMENSIONS:
Length: Hull 4,788mm, Total (front mud flap to rear of vice) 4,050mm
Height, to top of hull: 1,718mm
Height, to top of machine gun: 2,254mm
Width, overall (towbar/jib stowage strap to stowed spade): 2,405mm
Width, over tracks: 2,134mm
Ground clearance: 356mm

ARMAMENT:
Pintle-mounted: 7.62 GPMG
Smoke launchers: Two off four-barrelled smoke launchers

SIGHTING AND VISION SYSTEMS:
Commander's: No.27 Mark 1 Cupola: five unity periscopes No.42 Mk 1, x1 day sight (No.44 Mk 2) and interchangeable passive night sight
Driver: Unity periscope (No.44 Mk 2), interchangeable passive night sight (AV, II, L16A1)
Crew compartment: One vision block in rear door
Communications: Clansman

ENGINE:
Jaguar 4.2l J60 No1 Mark 100B petrol six-cylinder
Capacity: 4.235l
Max power: 190bhp at 4,750rpm
Max torque: 345.8Nm at 3,500rpm
Generator: 140 amp 28V
Transmission: TN15X Cross drive semi-automatic, seven forward and reverse speeds
Suspension: Transverse torsion bars, 203mm bump, 102mm rebound. Shock absorbers front and rear stations

Tracks: Light steel rubber bushed, width 432mm, pitch 116mm. Links per side: 84

PERFORMANCE:

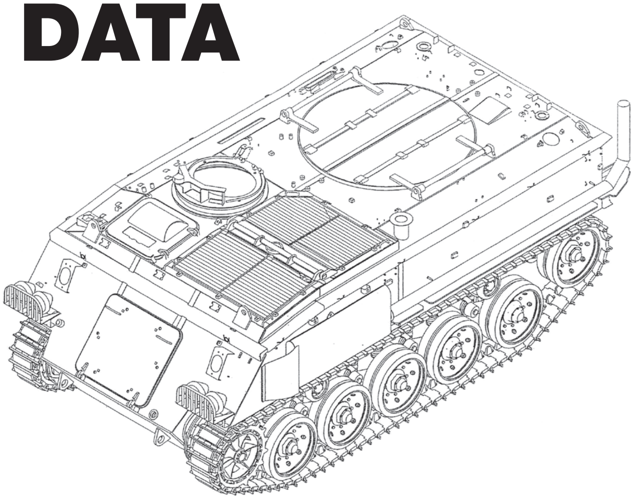
Maximum road speed: 72.5kph
Acceleration: 0–48.3kph (0–30mph) in 25s
Vertical obstacle: 500mm
Angle of approach: 26 degrees
Angle of departure: 21.5 degrees
Maximum gradient – stop/start: 45 per cent (24 degrees)
Fording, screen stowed: 1,067mm
Swimming: 6.44kph with tracks, 9.65kph with propeller kit and washboard

WINCH:

Twin capstan
Maximum pull: 14.23 tonnes with 4:1 snatch block
Speed: 122m/minute
Rope length: 229m
Anchor spade: Two-pronged spade with removable centre section
Fuel capacity: 404.51l
Range on roads: >483km
NBC: Collective protection system with No.5 Mark 1 NBC pack

APPENDIX F: FV430 SERIES DATA

FV432



FV432 Isometric view. (Crown Copyright MOD)

Data from: Mark 1: FVRDE Specification 9309
Mark 2: FVRDE Specification 9320

Crew: Two: commander, driver,
Dismounts: 10

WEIGHT:
Unladen: 13.24 tonnes Mark 1, 13.607 tonnes Mark 2
Laden: 14.77 tonnes Mark 1, 15.104 tonnes Mark 2
Ground pressure: 0.79kg/cm^2

DIMENSIONS:
Length overall: 5.105m
Length hull only: 4.826m
Width overall: 2.641m Mark 1, 2.972 Mark 2
Width over tracks: 2.527m
Height of roof: 1.879m
Height to top of machine gun: 2.286m
Ground clearance: 0.406m
Armament: Pintle mounting for 7.62 GPMG
Smoke launchers: Discharger, grenade, multi-barrel No.8 Mark 1 three barrel launchers (two off)

SIGHTING AND VISION SYSTEMS:
Commander: 360-degree rotation cupola with three periscopes
Driver: Single wide-angle periscope with IR swap sight
Armour: Maximum 16mm

ENGINE:
Mark 1: Rolls-Royce B81 Straight 8 Petrol Engine
Capacity: 6.5l
Power: 220bhp at 3,750rpm
Torque: 45.6kg/m at 2,750rpm

ENGINE:
Mark 2: Rolls-Royce K60 Mark 4 six-cylinder opposed piston
Capacity: 6.57l
Power: 240bhp at 3,750rpm
Torque: 52.37kg/m at 2,500rpm
Transmission: Allison TX200-4A six speed
Steering: Controlled differential
Suspension: Torsion bar
Tracks: Single pin rubber bushed. Width 242.9mm, pitch 116.6mm

PERFORMANCE:
Maximum road speed: 52kph
Vertical obstacle: 609.6mm
Gradient: 35 degrees
Shallow fording: 1.828m

Trench: 2.06m
Fuel capacity: 454l
Range: 424km Mark 1, 480km Mark 2
NBC: Collective protection system with No.1 Mark 2 NBC pack

FV433 ABBOT

Crew: Four: No.1, driver, loader, layer plus two ammunition numbers (these normally travelled on the limber vehicle)
Weight: 16.556 tonnes

DIMENSIONS:

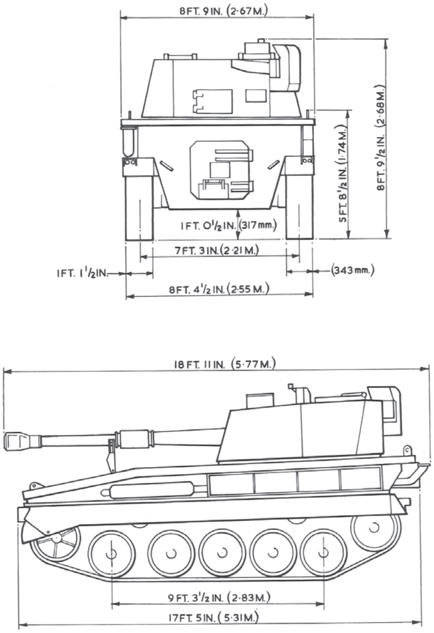
Length:
Hull: 5.08m
Gun front: 5.77m
Height:
Roof: 2.34m
Cupola: 2.49m
Top of sight cover: 2.68m
Width: 2.67m
Width over tracks: 2.55m
Ground clearance: 0.41m

MAIN ARMAMENT:

QF 105mm L13A1 32 calibre shot travel.
Maximum range 17,548m
Elevation: -5 to +70 degrees
Turret race ring diameter: 80 inches
Traverse: 230 miles/second
Internal ammunition stowage: 40 rounds
Auxiliary armament: Pintle mounting for .30in. Browning or 7.62 GPMG
Smoke launchers: Discharger, grenade, multi-barrel No.8 Mark 1 three barrel launchers (two off)

SIGHTING AND VISION SYSTEMS:

Layer: 14in. periscopes dual sight and telescope for anti-tank role
Commander: 3 x periscopes
Driver: Wide-angle periscopes and II swap sight



FV433 Abbot dimension diagram. (Crown Copyright MOD)

Armour: 12mm maximum providing protection against small arms and shell splinters
Communications: B48 radio

ENGINE:

Rolls-Royce K60 2 Stroke CI six-cylinder
Power (gross): 240bhp at 3,750rpm
Torque: 52.5Nm at 2,500rpm

TRANSMISSION:

Allison TX 200 six-speed gearbox
Cletrac steer and braking unit
Suspension: Five road wheels per side on Torsion bar suspension with friction shock absorbers front and rear wheel stations
Tracks: Single pin bushed and padded, pitch 4.59in., Width 13.5in.

PERFORMANCE:
Road speed: 47 kph
Vertical obstacle: 0.610m
Maximum gradient: 30 degrees
Trench: 2.06m
Minimum radius of turn: 5.35m
Gap crossing: 2.57m

FLOTATION:
Collapsible screen
Freeboard: 18in. 5.6 kph
Fuel: 386l with 82l reserve
Range on road: 368km

FV434

Type: Carrier maintenance full tracked
Crew: Four: driver, commander, two fitters
Weight: Unladen, 15.044 tonnes; Laden, 17.746 tonnes
Payload: 2,703kg

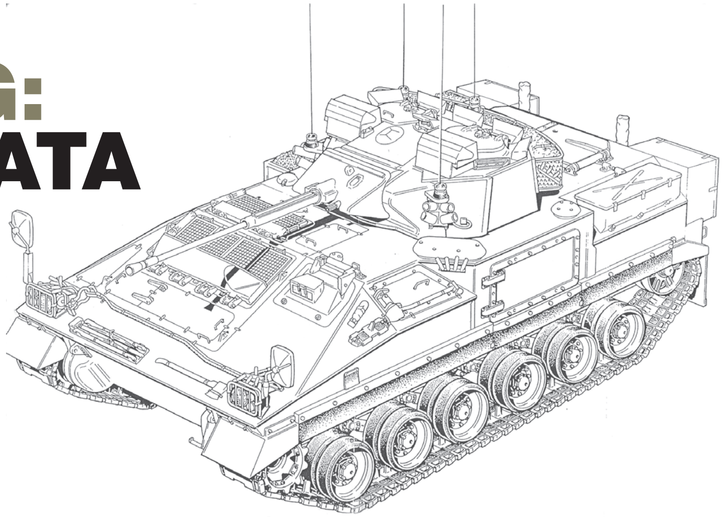
DIMENSIONS:
Length: 5.85m
Height to roof: 1.89m
Height over lifting device when stowed: 2.79m
Width: 2.84m
Width over tracks: 2.53m
Ground clearance: Unladen, 0.368m; Laden, 0.343m
Armament: Pintle-mounted Bren gun 7.62mm
Smoke launchers: Two multi-barrel smoke dischargers

SIGHTING AND VISION SYSTEMS:
Commander: three fixed periscopes
Driver: One wide-angle periscope with II swap sight
Armour: 16mm max
Communications: C13, C42 and C45 radios

ENGINE:
RR K60 opposed piston two-stroke: 6.57l
Power (gross): 240bhp at 3,750rpm
Torque: 52.5kg/m at 2,500rpm
Transmission: Gearbox GM/Allison TX200 – 4B; steering-controlled differential unit
Suspension: Five road wheels, torsion bar suspension; lock-out dampers front and rear stations
Tracks: Width 342.9mm, pitch 116.6mm; 91 per track

PERFORMANCE:
6th gear: 47.2kph
5th gear: 33.8kph
4th gear: 24.3kph
3th gear: 17.5kph
2th gear: 12.4kph
1th gear: 8.9kph
Reverse: 7.8kph
Vertical obstacle: 0.610m
Gradient: 30 degrees
Trench: 2.06m
Minimum radius of turn: 5.35m
Crane: Hiab Type 61 crane: 2.586kg lift at 2.50m radius
Fuel: 454l
NBC: Collective protection system with No.9 Mark 1 NBC pack

APPENDIX G: WARRIOR DATA



Warrior isometric drawing from User Handbook. (Crown Copyright MOD)

FV510: WARRIOR SECTION VEHICLE

Crew: Ten (Commander, Gunner, Driver, plus 7 dismounts)

Weight: Total battle weight: 25.4 tonnes

DIMENSIONS:

Length: 6,340mm

Length over tracks: 5,980mm

Height: to hull top 1,936mm

Height: to turret top 2,770mm

Width: 3,089mm

Ground clearance: 505mm

MAIN ARMAMENT:

L21A1 30mm RARDEN cannon, QF Fixed Ammunition

Elevation: 45 degrees

Depression: 10 degrees

Ammunition stowage: 225 (Including six in breech)

Coaxial weapon: 7.62mm L94A1 chain gun, mounted to the left of the main armament

Smoke dischargers: Two off L8 No.12 Mark II mounted on turret

SIGHTING AND VISION SYSTEMS:

Commander and gunner's main sight: Raven Mark 1 L7A2 x6.4 II sight and x8 day sight

Turret unity vision: Seven off AV No.40 Mk 3 periscopes, one off AV No.32 Mk 2 rotatable periscope

HULL VISION DEVICES:

Roof: Two No.30 periscopes; Mark 3 LHS, Mark 4 RHS

Rear door: Armoured vision slot

Driver's sights: Day No.44 sight, night L16 A1 II

BGTI: Upgraded commander's sighting fit to include a colour camera and the gunner's fit to include a monochrome camera, thermal imager with wide and narrow field of view and a laser range finder

ARMOUR:

Main hull construction: Aluminium alloy to MVEE Specification 813

Turret construction: Rolled steel to MVEE Specification 816

Radio: Provision for 1xVRC 533 and 1xPRC351

ENGINE:

Rolls-Royce Condor CV8TCA

Power: 410kW at 2,300 rpm

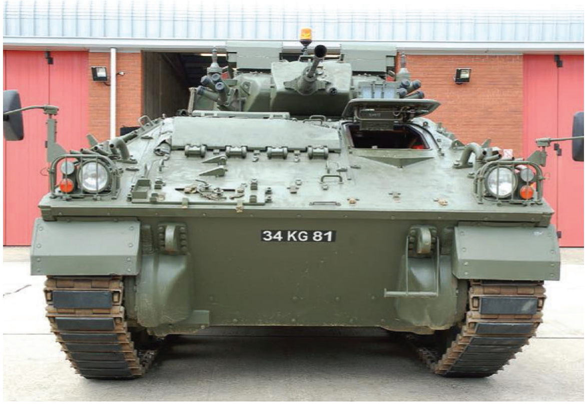
Torque: 1,900Nm at 1,500 rpm

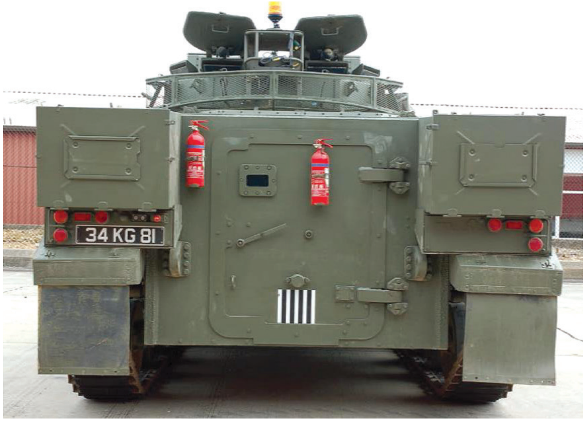
TRANSMISSION:

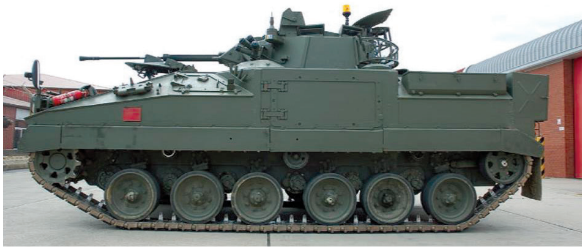
Allison X300-4B
Four forward and two reverse gears
Generator: 350 amp at 28.5V
Suspension: Torsion bar, bump 280mm, rebound 117mm
Dampers: Rotary Hydraulic Vane on one-, two- and six-wheel stations
Tracks: Single pin, width 450mm, pitch 152.4mm

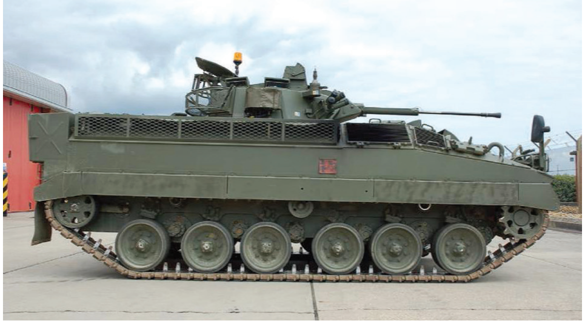
PERFORMANCE:

Maximum road speed: 75kph; reverse 48kph
Acceleration: 0–48kph (0–30mph) in 16s
Braking:
  Maximum deceleration: 0.43g
  Maximum stopping distance from 75kph: 62m
Slopes: including stop, start and held on foot or parking brakes 60 per cent
Side slope: 40 per cent
Gap crossing: 2.5m
Vertical obstacle: 0.75m
Wading depth: 1.3m









TOP LEFT BGTI Warrior front. (Crown Copyright MOD)

LEFT BGTI Warrior rear. (Crown Copyright MOD)

TOP BGTI Warrior left-hand side. (Crown Copyright MOD)

ABOVE BGTI Warrior right-hand side. (Crown Copyright MOD)

VOLUME:
Useable volume for crew and stowage: 8.43m3
Volume of external stowage bins: 0.84m3
Fuel capacity: 745l
Range: (On roads at an average speed of 60kph) 500km
NBC: Collective protection system with No.10 Mark 1 NBC pack

FV512 WARRIOR REPAIR VARIANT

Data from DGFVE Spec 469

Crew: Five: commander, driver plus three others
Weight: Total battle weight: 28.5 tonnes

DIMENSIONS:
Length: 6,675mm
Width: 3,130mm
Height: to hull top 1,936mm
Height: to turret top 2,802mm
Ground clearance: 490mm
Armament: 7.62mm L94A1 chain gun

SIGHTING AND VISION SYSTEMS:
Commander's sight: Raven Mark 1 L7A2 II sight and x8 mag day sight
Unity vision: 8 No.42 Mk 3 periscopes
Driver's sights: Day No.44 sight, night L16 A1 II

ARMOUR:
Hull material: Aluminium plate to MVEE Spec 813
Turret: Steel
Radio: VRC 531

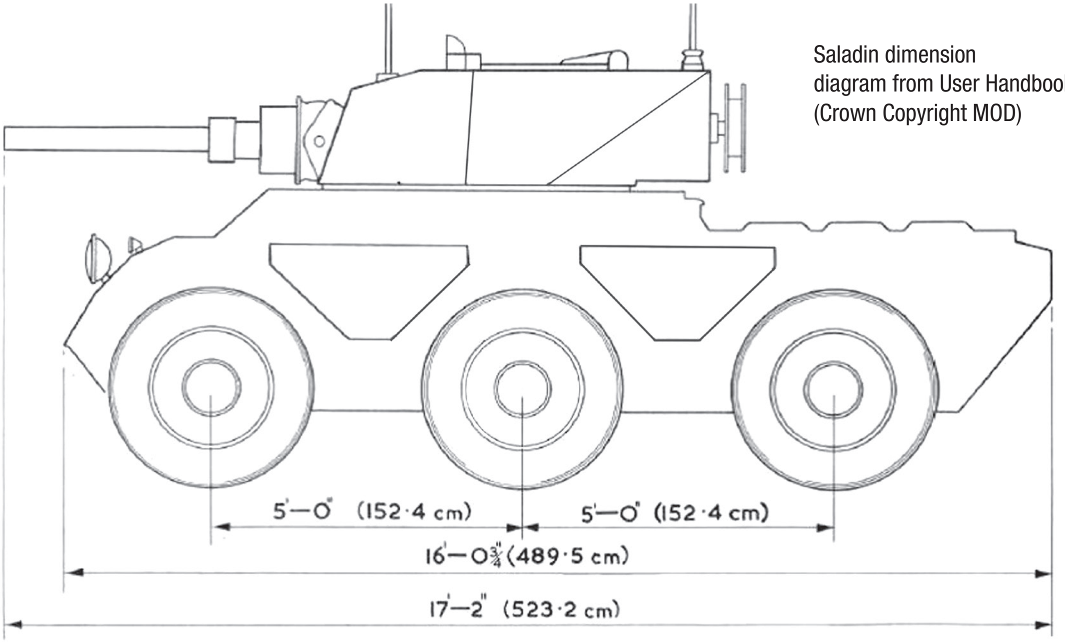
ENGINE:
Rolls-Royce Condor CV8TCA
Power: 410kW at 2,300rpm
Torque: 1,900Nm at 1,500rpm

TRANSMISSION:
Allison X300-4B
Four forward and two reverse gears

PERFORMANCE:
Max road speed 70kph
Acceleration: 0–48kph (0–30mph) in 19s
Slopes: including stop, start and held on foot or parking brakes 60 per cent
Side slope: 40 per cent
Gap crossing: 2.5m
Vertical obstacle: 0.75m
Wading depth: 1.3m

SPECIAL-TO-ROLE EQUIPMENT:
6.5-tonne crane with stabilizer and suspension lock-outs
Auxiliary Engine Yanmar Type 3TN66 11kW
Air compressor for powering tools
Towing hitch capable of towing a trailer with Challenger power pack
Fuel capacity: 745l
Range: (On roads at an average speed of 60kph) 500km
NBC: Collective protection system with No.10 Mark 1 NBC pack

APPENDIX H: SALADIN DATA



Saladin dimension diagram from User Handbook. (Crown Copyright MOD)

Data from User Handbook: Army Code 12232-10 Dated 1958

Crew: Three: commander/loader, gunner/operator, driver

WEIGHT:

Basic vehicle: 9.144 tonnes

Total battle weight: 11.278kg

DIMENSIONS:

Length, over gun: 5,232mm

Length, hull: 4,895mm

Height to top of turret: 2,172mm

Height to top of sight: 2,356mm

Width: 2,450mm

Wheel base: 3,084mm

Track: 2,038mm

Ground clearance: 441mm

ARMAMENT:

76mm AC L5A 10.30in. Browning coaxial machine gun. Provision for additional pintle-mounted 0.30 Browning machine gun

Smoke grenade launchers: No.80 system with No.1 Mark 7 launchers

SIGHTING AND VISION SYSTEMS:

Commander: Four off Periscopes AFV No.18 Mark 1, three forward of hatch, one to the rear

Gunner: Periscope, AFV No.17 Mark 2

Driver: Three off Periscopes, AFV No.17 Mark 1

ENGINE:

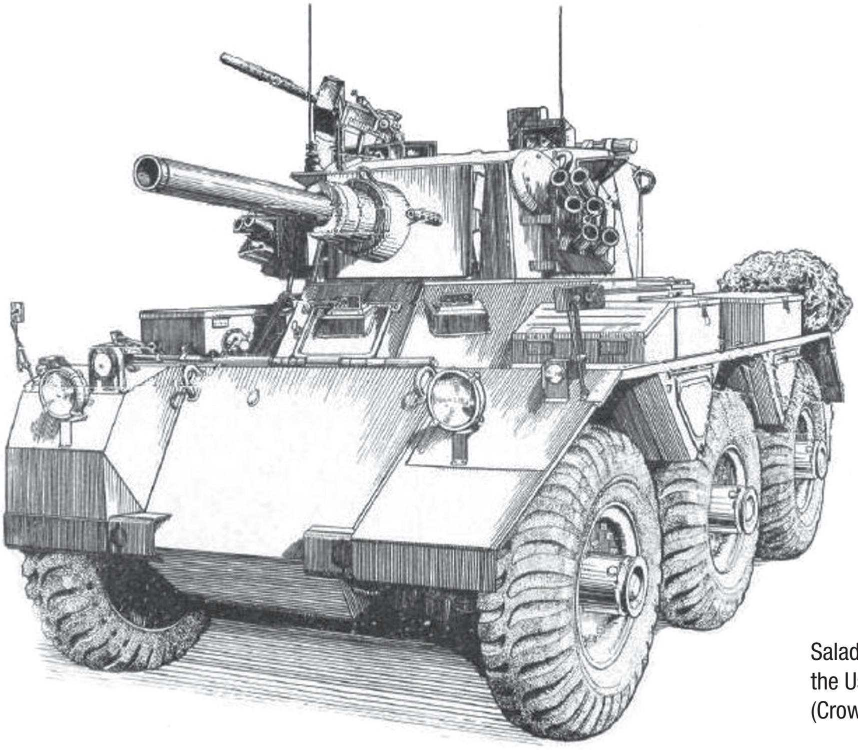
RR B80 No 1 Mark 6D. eight-cylinder in-line petrol
Power, gross: 160bhp at 3,750rpm
Power, nett, at flywheel: 136bhp
Torque: 257lb-ft at 1,750rpm
Gear box: Five-speed semi-automatic pre-select

GENERATOR:

Early vehicles: Generator No.2 Mark 1 or Mark 2, 25 amps at 28V
Later vehicles: Generator No.4 Mark 1, 75 amps at 28V (driven through two-speed gearbox)
Batteries: Two off 60 Ah 12V
Suspension: Fully independent torsion bar
Dampers: Double acting hydraulic – telescopic
Wheels: B8.00-20

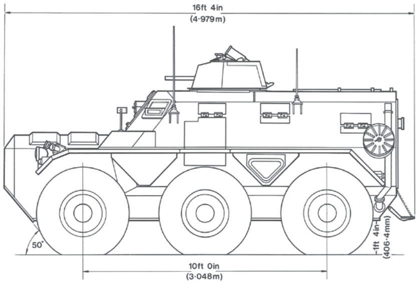
PERFORMANCE:

Maximum speeds:
  5th gear: 73.2kph
  4th gear: 45.4kph
  3rd gear: 26.7kph
  2nd gear: 15.4kph
  1st gear: 7.1kph
Maximum gradient: 24 degrees
Ditch crossing: 1.524m
Approach angle: 60 degrees
Departure angle: 50 degrees
Turning circle: 14.63m
Fording depth:
  Unprepared: 1.067m
  Prepared: 2.136m
Fuel capacity: (including 11-gal reserve tank): 240.8l
Range (road): 402km



Saladin drawing from the User Handbook. (Crown Copyright MOD)

APPENDIX I: SARACEN DATA



Saracen dimensions. (Crown Copyright MOD)

Saracen Data from FVRDE Specification 9,125

Crew: APC: driver, section commander plus ten passengers
Weight: Unladen: 7.711 tonnes; Laden: 9.07 tonnes

DIMENSIONS:

Length, vehicle: 4,851mm
Length including towing hook: 4,978mm
Height: Top of hull: 1,981mm
Top of turret: 2,438mm
Width: 2,515mm
Ground clearance: 406mm
Track: 2,032mm
Wheelbase: 3,048mm

ARMAMENT:

Turret machine gun, .30 Browning
Mounting ring for Bren Gun over roof hatch for AA defence use. Eight small arms firing ports (three each side and one in each of the rear doors). Smoke grenade launchers: No.80 system

SIGHTING AND VISION SYSTEMS:

Commander: Periscopes sight No.3 Mark 1
Driver: Three periscopes No.17 Mark 1
Communications: Wireless sets No.19, 19B and 31 AFV (or 68T if No.31 AFV not available)
Armour: Steel armour 14mm maximum on hill, 16mm turret

ENGINE:

RR B80 Mark 3A or 6A eight-cylinder in-line petrol
Capacity: 5674cc
Power: 160bhp gross, 136bhp net (at flywheel) at 3,750rpm
Torque: 285lb-ft gross, 257 at 1,750rpm
Transmission: Five-speed semi-automatic pre-select epicyclic
Tyres: 11.00-20 run flat Type L
Suspensions: Fully independent wishbone linkage with torsion bars
Bump: 127–152mm
Rebound: 102–127mm

ELECTRICAL SYSTEM:

Two-speed dynamo (early vehicles single speed)
24V Two off 12V 60-amp batteries

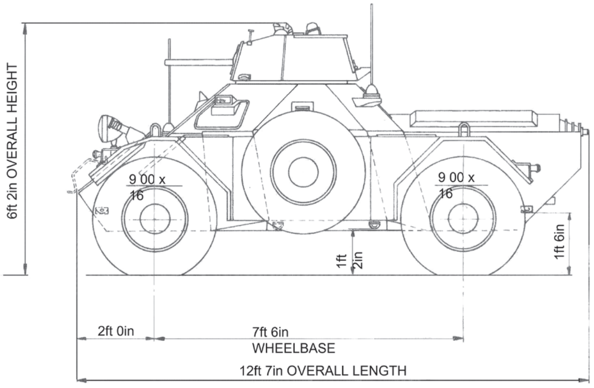
PERFORMANCE:

Maximum speed: 68.9kph
Acceleration in top gear: 16.1 to 48.3kph (10 to 30mph) in 27 seconds
Gradient: 24 degrees
Side angle: 45 degrees
Vertical obstacle: 457mm
Approach angle: 50 degrees
Departure angle: 50 degrees
Turning circle: 13,716mm
Fording:
shallow, unprepared: 1,067mm
deep, prepared: 1,981mm
Fuel capacity: 227.3l (50 gallons – 40 main tanks, ten reserve tanks)
Range: 402km

APPENDIX J: FERRET DATA

FV701(J) FERRET SCOUT CAR LIAISON MARK 1

Data is for Mark 1/1, data for the Mark 1 with swimming screen and the Mark 1/2 is in brackets where it varies from the Mark 1/1.



Ferret Mark 2 dimensions. (Crown Copyright MOD)

Crew: Two or three (Driver, Commander, plus additional seat)

WEIGHT:
Unladen: 3.51 tonnes (3.64 tonnes with wading kit) (3.66 tonnes Mark 1/2)
Laden: 4.21 tonnes (4.35 tonnes with wading kit) (4.37 tonnes Mark 1/2)

DIMENSIONS:
Length: 3.84m (1.91m with wading kit)
Height: 1.45m (1.65m Mark 1/2)
Width: 1.91m
Wheelbase: 2.29m
Armament: Pintle-mounted 0.303 Bren Gun
Smoke launchers: Discharger smoke grenade (two off) No.80 system
Sighting and vision system: Driver: Periscope No.17 (three off)
Armour: Hull structure, welded steel providing protection up to 0.5in. armour piercing (AP)

ENGINE:
RR B60 in-line Mark 6A cylinder petrol engine
Capacity: 4.225l
Power: 96.75kw at 3,750rpm
Torque: 265Nm at 2,000rpm

TRANSMISSION:
Five-speed semi-automatic gearbox with fluid coupling
Generator: 25 amp at 24V

SUSPENSION:
Double wishbone independent with coil springs and hydraulic shock absorbers
Bump: 152.4mm rebound 140mm
Tyres: 9.00x16 Run Flat

PERFORMANCE:
Road speed: 72kph
Gradient for stop/start: 30 per cent
Gradient maximum gradeability: 46 per cent
Turning circle between kerbs: 11.58m
Approach angle: 55 degrees
Departure angle: 47 degrees
Wading: without preparation: 0.9m (0.91m Mark 1/2)
Fuel capacity: 96l
Typical road range: 305km

FV712 FERRET MARK 5

(FVRDE Spec 9366)

Chassis: Ferret Mark 3 to FVRDE Specification 9358
Crew: Two (Commander, Driver)

WEIGHT:
Unladen: 4.53 tonnes
Laden: 5.26 tonnes

DIMENSIONS:
Length: 4,140mm
Height:
  Unladen: 2,045mm
  Laden: 2,013mm (top of turret)
  1,448mm (top of hull)
Width: 2,159mm
Wheelbase: 2,286mm
Ground clearance (minimum at rear axle):
  Unladen: 381mm
  Laden: 355.6mm

ARMAMENT:
Swingfire missile: Four in launcher tubes, plus two spares. Launcher tube elevation: 35 degrees
Turret-mounted L8 GPMG
Smoke launchers: Discharger smoke grenade, No.10 Mark 1 or Mark 2 (two off)

SIGHTING AND VISION SYSTEMS:
Turret: Avimo monocular split field periscope AFV 43 sight
Driver: Periscope No.17 (three off)
Communications: Mounting for either a C13/B47 or C42/B47

ARMOUR:
Turret structure: Welded aluminium (75mm maximum) providing 7.62 AP protection
Hull structure: Welded steel, protection up to 0.5in. AP

ENGINE:
RR B60 in-line six-cylinder petrol engine
Capacity: 4.225cm^3
Power: 129bhp at 3,750rpm
Torque: 284 Nm at 2,500 rpm
Transmission: Five-speed semi-automatic gearbox with fluid coupling
Generator: 25 amp at 24V

SUSPENSION:
Double wishbone independent with coil springs and hydraulic shock absorbers
Bump 6in., rebound 5.5in.
Tyres: 11.00-20 run-flat high-speed cross-country type

PERFORMANCE:
Road speed: 80kph
Acceleration: 20–40mph in 22s (32kph to 64kph)
Gradient for stop/start: 24 degrees
Turning circle between kerbs: 12.192m
Wading: without preparation: 1,016mm
Swimming: Entry and exit slopes 25 degrees, speed 3.9kph
Fuel capacity: 77l main, 15l reserve
Typical road range: 225km

APPENDIX K:
FV721 FOX DATA

Data from MVEE Specification 9383

Crew: Three: commander, gunner, driver

WEIGHT:
Maximum battle weight: 6,350kg
Ground pressure: 720kN/m^2
Air transportability: Three in C130

DIMENSIONS:
Length, gun forward: 5,080mm
Length, hull: 4,220mm
Height to top of turret: 1,980mm
Height to top of commander's sight: 2,200mm
Width: 2,135mm
Wheelbase: 2,465mm
Ground clearance: 410mm

ARMAMENT:
30mm L21A1 RARDEN
Elevation: -14 degrees to +40 degrees
Ammunition: 93 rounds
Coaxial weapon: L37A2 7.62 GPMG

SMOKES LAUNCHERS:
One off four-barrel smoke launcher (No.12 Mark 1) on LHS of turret
Two off two-barrel smoke launcher on RHS of turret

SIGHTING AND VISION SYSTEMS:
Commander: Sight, periscope AV No.68 Mark 1 x1/x10 day sight
  Seven unity periscopes AV No.43 Mark 3
Gunner: Sight, periscope AV No.52 Mark 1 x1/x10 day sight
  Sight periscope, AV, II L2A1 passive night sight
  Two unity periscopes AV No.43 Mark 3
Driver: Periscope, AV, No.44 Mark 2 wide angle
Periscope, AV, II, L17A1 passive II swap sight
Communications: Clansman

ENGINE:
Jaguar J60 No 1 Mark 101A petrol six-cylinder in-line
Capacity: 4.235l
Max power: 176bhp at 4,500rpm
Maximum torque: 3,732Nm at 3,200rpm
Gear box: Daimler pre-select epicyclic five-speed
Generator: 140 amp at 28V
Suspension: Independent double wishbone with 152mm bump, 140mm rebound
Tyres: 11.00-20 run flat

PERFORMANCE:
Maximum road speed: 105kph
Acceleration: 0–48kph (0–30mph) in 9s
Maximum gradient, stop/start: 30 degrees (58 per cent)
Speed in water: 5kph
Fording: 1,016mm
Approach angle: 65 degrees
Departure angle: 55 degrees
Turning circle: 13.72m between walls
Fuel capacity: 145.47l under armour, 38.63l in two external jerrycans
Range on roads: 430km

INDEX

References to images are in **bold**.

1-Ton Armoured 4x4 Humber (‘Pig’) 270–71

Advanced Composite Armoured Vehicle Programme (ACAVP) 246
AEC Ltd 15
Afghanistan 10, 165, 188, 220, 226
AFV *see* Armoured Fighting Vehicle
air-transportability 173, 174, 252
Alvis 151, 177, 189, 193, 242
  Ferret 261
  Saladin 250
ambulance roles 185, 204, **205**, 219, 231, 271
amphibious vehicles 39–40, 45, 200, 257–58, 273
Angolan Civil War (1978–2002) 31
Anti-Tank Guided Weapons (ATGW) 65–66
anti-tank weapons 29, 141
AORG *see* Army Operational Research Group
APC *see* Armoured Personnel Carrier
APDS *see* Armour Piercing Discarding Sabot
Armaments Research and Development Establishment (ARDE) 57, 62, 102
armour 116
  Centurion 21
  Challenger 1; 128, 130
  Chieftain 83–84, **85**
  Conqueror 44, 45, 46–47
  MBT80; 121
  Stormer 189–90
Armour Piercing Discarding Sabot (APDS) 18–19, 22, 62
Armoured Engineer Vehicle (AEV): Chieftain 93–95, **96**
Armoured Fighting Vehicle (AFV) 105–10
  Ferret 256–61, 263–64
  ‘for the 80s’ project 193–94, 233–37, **238**, 239
  see also Saladin; Saracen
Armoured Personnel Carrier (APC) 194, 218
Armoured Recovery Vehicle (ARV) 37–38
Chieftain 90–91
Conqueror 51–52
Armoured Repair and Recovery Vehicle (ARRV)
Challenger 1; 137, **138–39**, 140–41
Chieftain 90–91, **92**
Armoured Vehicle Reconnaissance (AVR) 172–73, **248–49**
Armoured Vehicle Royal Engineers (AVRE) 35, **36**, 95–96
Army Council 14
Army Operational Research Group (AORG) 46, 63–64, 66, 67
Asal Uttar, battle of (1965) 30
ATGW *see* Anti-Tank Guided Weapons
Australia 173, 189, 251, 252, 258
Australian Army 31–32
Austria 56, 57
autoloaders 154–55, 156, 162–63
Automotive Test Rig (ATR) 120–21
AVLB *see* Chieftain

Bahrain 252
Bailey bridge 15
Balkans 10, 147
BAOR *see* British Army of the Rhine
Battery Command Vehicle (BCV) 230
Battle Group Thermal Imager (BGTI) 188
  Warrior 225–26
Beach Armoured Recover Vehicle (BARV) 40–41
Berlin Wall 244
Binh Ba, battle of (1969) 31–32
Bosnia 131
  CVR(T) 188
  FV434 carrier **211**
  Warrior 220, 226
BOXER 247

Brazil 279
bridge layers **238**, 239
  Centurion 34
  Challenger 2; **146**, 147
  Conqueror 45
  Stormer 193
Bridges, battle of the (1990) 90
British Aircraft Corporation (BAC) 23
British Army 9, 10, 186–87
  1st Royal Tank Rgt 29
  3rd Rgt Royal Horse Artillery 198
  5th Royal Inniskilling Dragoon Guards Rgt 28–29
  5th Royal Tank Rgt 18
  7th Armoured Bde (Desert Rats) 131
  8th Kings Royal Irish Hussars Rgt 28, 29
  11st Hussars Rgt 77
  14/20th Hussars Rgt 48
  32nd Armoured Engineer Rgt 35
British Army of the Rhine (BAOR) 55
  Centurion 37, 40
  Challenger 1; 127–28, 141
  FV432 carrier 201, 203
  FV433 Abbot 208–9
  Oxford carrier 196
  Warrior 223

Callaghan, James 118
Canada 101, 103, 172–73, 189, 258
'Canal Defence Light' (CDL) system 16
carriers, British:
Cambridge (CT25) 196–98
  FV420; **198**, 199–200
  FV430 Engineer variants 213–14
  FV430 Signals variants 214–15
  FV431; **200**
  FV432; 201, **202**, 203–7
  FV433 Abbot 207–10
  FV434; 210–12
  FV436; 215–16
  FV437 Pathfinder 217
  FV438 Swingfire 217–18
  Oxford (CT20) 194–96
  see also Warrior
carriers, US: M1 Bradley 221
Carter, Jimmy 118
Centurion 14–19, 65
  data 289–91
  designations 23, 26–27
  Marks 19–23, **24–25**, 27
  service use 28–32
  variants 33–42
CET *see* Combat Engineer Tractor
Challenger 1; 95, 127–37, 295–96
  variants 137, **138–39**, 140–41, **142–43**
Challenger 2; 144–48, **149**, 161–62
Chertsey 9–10, 67, 144
  AFVs 240
  carriers 194–96
  concept studies 98, 151–52
  wheeled armoured vehicle reconnaissance 262
Chieftain 23, 27, 69–73, 76–90, 123
  data 292–94
  engine 152, **153**
  Mark 3; **74–75**
  replacements 103, 105–10, 117, 144
  variants 90–97
Chieftain/Challenger Improvement Programme (CHIP) 133–35
China 29
Chobham armour 219–20
Chobham Common *see* Chertsey
Christie suspension 16
Clansman radios 87
Combat Engineer Tractor (CET): FV180; 272–73
Combat Vehicle Reconnaissance (Tracked) (CVR(T)) 168, 173–74, 175–77, 193–94, 297–301
  FV series **176**, 177–78
  FV101 Scorpion 179–80
  FV102 Striker **166**, 180–81
  FV103 Spartan 184, **186**
  FV104 Samaritan 185, **186**
  FV105 Sultan 185–86
  FV106 Samson 186, **187**
  FV107 Scimitar 179–80, **182–83**
  FV4333 Stormer 189–93

  operational use 186–89
  TV15000; 174–75
Component Technology Demonstrator Programme (CTDP) 96, 154–55
concepts 98, 103–4, 105–10, 147–48, **149**; *see also* future concept studies; Vehicle Concepts; Wheeled Armoured Vehicle Reconnaissance concepts
Conqueror 43–53, 54, 65
Cordingley, Gen. Patrick 128, 130–31
'Crazy Horse' 96
crew 155
  Centurion 16–17
  Conqueror 46–47
  Contentious 98, 99, 101
  CVT(T) 179
  Ferret 259–60
  Saladin 251
  Vixen 265
cupola 23
CVR(T) *see* Combat Vehicle Reconnaissance (Tracked)

Defence Evaluation and Research Agency (DERA) 9
Defence Research Agency (DRA) 9
Defence Science and Technology Laboratory (Dstl) 9
Department of Tank Design (DTD) 9, 14, 15, 18
desert trials 21, 131–32, 200
dozer blade 35, **36**, **88**
  Challenger 1; **137**, 141
  Conqueror 44, 45
Dutch Army **28**
Dynamometer Car 53

Egypt *see* Suez Crisis; tanks, Egyptian
electrical stabilization 18
Elliot, Ted 83
engines 152–53
  A46; 168, 169
  Centurion 16, 17, 27, 37
  Chieftain 77–80, **81**, 88–89
  Conqueror 45, 47–48
  CVR(T) 174–75, 188
  Saladin 251
English Electric 43
Evolutionary National Tank (ENT) 144, 156–60
Executive Committee of the Army Board (ECAB) 105

Fairey Engineering 67, 68
Falklands War (1982) 10, 41, 186–87
Family of Light Armoured Vehicles (FLAV) 240–45
Ferret 256–61, 311–12
Fighting Vehicles Design Department (FVDD) 9, 195–96
Fighting Vehicles Research and Development Establishment (FVRDE) 9, 20, 67, 76, 104–5
  Charioteer 55–56
  Conqueror 48–49, 50, 52
Finland 56
Fire Control Rig (FCR) 119–20
flame-throwing equipment 36, 45, 46, 170
Forward Repair Vehicles (FRV) 211, **212**, 228–30
France 258
fuel 20, 21
fume extractors 20, 51
future concept studies 150–65
Future Rapid Effects System (FRES) 232, 247
FV430; 204, 213–15, 302–4
FV721 Fox 313
FVRDE *see* Fighting Vehicles Research and Development Establishment

gap-crossing vehicles 34–35
gas turbines 52–53
gearbox:
  Centurion 17
  Chieftain 76, 78
  CVR(T) 176–77
  FV4030; 125
  Stormer 191
  see also reverse gear
Germany 76, 234–35, 252, 274; *see also* tanks, German

Ghana 252
Gibb, Sir Claude 14
GKN Sankey 199, 200, 201, 203, 242
  Saxon 276, 277
  Warrior 220, 221
Golan Heights *see* Yom Kippur War
Government Aircraft Factories (Australia) 67

High Explosive Anti-Tank (HEAT) 104
High Explosive Squash Head (HESH) 22, 35, 209
  Soviet threat tanks 57, 61–63, 66
hit data 64
Hong Kong 253, 256
hot weather trials 21, 80, 198, 203
  Saladin 251
  Saracen 253
Hungarian Revolution (1956) 22
'Hunter-Killer' mode 50

Improved Computer Sighting System (ICSS) 84, 129
Improved Fire Control System (IFCS) 82–83, 84
Improvised Explosive Devices (IEDs) 188
India 207, 209, 278
Indian Army 30
Indo-Pakistan War (1965) 30
Indonesia 189, 252, 256
Infantry Fighting Vehicle (IFV) 218–19, 221–22
infrared 23
Iran 81, 123–26
Iran–Iraq War (1980–88) 83, 90
Iraq 10, 147, 188, 207
  Warrior 220, 226
Israel 30–31, 80–81
Italy 274

Japan *see* tanks, Japanese
Jordan 56, 126–27, 132, 252, 256
Joseph Sankey Ltd 20

Kenya 252
kill data 64
Kirkcudbright 18, 42, 57, 67, 96, 262
Korean War (1950–53) 10, 19, 28–29, 37, 196
Kosovo Force (KFOR) 147
Kuwait 10, 188, 252, 256
  Chieftain 81, 90
  Warrior 220, 226
  see also operations: *Granby*

Lebanon 57, 252, 256
Leyland Motors 21, 71, 72
Libya 21, 198, 252, 256
light tanks, British:
  A46; 168–9
  FV series 169–72
light tanks, US: M551 Sheridan 173
Lightweight High Mobility Tracked Vehicle (LHMTV) 173
liquid propellants (LPs) 102, 161
Long Dien, battle of (1968) 31

Main Battle Tanks (MBTs) 16
Malaysia 189, 252
Malkara missile 67, **68**
mantlet 23
Mechanised Infantry Combat Vehicle (MICV) 105, 219–20, 233–37, 239
Meteor engine 17, 45, 47–48
Metropolitan Vickers 18
Military Engineering Experimental Establishment (MEXE) 34, 53, 200, 272
Military Vehicles and Engineering Establishment (MVEE) 9, 150–51
  Challenger 1; 137
  Chieftain 83, 96
  MBT80; 117–18
  UK/German Future Main Battle Tank 112–13
  Warrior 219–20
mine launching 190–93, 214
Ministry of Defence 9
Ministry of Supply (Farringdon) 21
missiles, British 184, 190, 257, 259–61
  Swingfire 23, 67–68, 180–81
  Trigat anti-tank 141, 231–32

Mobile Direct Fire Equipment Requirement (MODIFIER) 164–65
Montgomery, FM Bernard 43
Muller, Alfred 53
Multi-Role Armoured Vehicle (MRAV) 245, 246–47

Nelson, Maj 29
Netherlands 20, 81
Nigeria 252, 256
night operations 16
Northern Ireland 254, 271, 277
Nuclear, Biological and Chemical (NBC) protection system 76, 77, 81–82
nuclear weapons 32

Observation Post Vehicle (OPV) 230–31
Offord, Col. Eric 30
Oman 81, 146, 189, 190, 252
operations:
  Commando (1951) 28
  Granby (1991) 35, 130–31, 141, 190–91, 244, 261
  Sentry (1945) 15
  Telic (2003) 141
  Tong and Hammer (1969) 31–32
Orange William missile 67, **68**

Pakistan 30
Panther Command and Liaison Vehicle **241**
Portugal 252
prototypes:
  Centurion 15–18
  Challenger 1; 129, 140–41
  Challenger 2; 146
  Chieftain 73, 76
  Conqueror 45, 46–49
  CVR(T) 177
  Ferret 258–59
  Fox 264
  FV4030; 124
  light tanks 170–71
  MBT80; 122–23
  Saladin 250, 251
  Warrior 222–23, **225**

Qatar 256
QinetiQ 9

Rackham, G. J. 15
radar 215–16
radio 215; *see also* Clansman radios; remote control vehicles
railways 15
range 20, 48, 88, 131
Rapier crane 96
reconnaissance 172, 245; *see also* Armoured Vehicle Reconnaissance (AVR); Wheeled Armoured Vehicle Reconnaissance concepts
remote control vehicles 96
remote vision 155–56
reverse gear 15
rockets 97
Rolls-Royce 17, 196, 197
Rover 17
Royal Air Force (RAF) 253
Royal Armaments Research and Development Establishment (RARDE) 9
Royal Armoured Corps (RAC) 44, 46, 48
Royal Electrical and Mechanical Engineers (REME) 37, 80
Royal Engineers (RE) 214, 253
Royal Ordnance Factory (ROF) 15, 123, 129, 134, 159, 201
  FLAVs 242

Saladin 23, 172, 173, 250–52, **254**, 308–9
Sankey, Joseph 270, 271
Saracen 173, 252–56, 310
Saudi Arabia 279
Saxon 276–77
Schmidt, Helmut 118
Scout Vehicles 172
Self-Propelled Howitzer 274–75
Shadni, Col. Iska 30
Sierra Leone 252
Signature Classification and Reduction (SCAR) programme 153–54
Signature Integration Demonstrator (SID) 96, 153–54

SIKA International 246
Singh, Maj. Gen. Gurbaksh 30
Six Day War (1967) 30, 57
snorkelling systems **87**, **88**, 89
South Africa 256, 258
South African Army 31
Soviet Union 10, 146; *see also* tanks, Soviet
speed 48, 130
Sri Lanka 252
stabilization 18
stowage:
  Centurion 37
  Challenger 1 128–29
  FV420; **199**, 200
  Vixen 265, 267
Sudan 256
Suez Crisis (1956) 30
suspension 49
Sweden 20; *see also* tanks, Swedish
Switzerland 81
Syria *see* tanks, Syrian 31

tanks, British:
  Cambridge Carrier 98–99
  Charioteer 55–57, **58**, 65
  Comet 16, 17, 19, 55
  COMRES 75; 104–5, 106
  Contentious 98–99, **100**, 101–2
  Conway 55, **56**, 65
  Cromwell 17, 29, 55, 56, 169
  FV215; 66–67
  FV4010; 66–67, **68**
  FV4030; 123–27
  Heavy Gun Tank Mark 2; 57–59, **60**, 61
  Kinship 116–17, 125–26
  MBT80; 117–23, 129, 132–33
  PIP87; 158–59
  Prodigal 102–3
  Stuart IV 169
  see also Centurion; Challenger 1; Challenger 2; Chieftain; concepts; Conqueror; light tanks, British; UK/German Future Main Battle Tank
tanks, Egyptian 30
tanks, French 131–32, 144
tanks, German:
  Jagdtiger 52–53
  Leopard 1; 22, 80
  Leopard 2; 114, 123, 144
  Tiger 15
  see also UK/German Future Main Battle Tank
tanks, Japanese: Type 74; 22
tanks, Soviet 123
  JS2; 72
  JS3; 46, 72
  T34/85; 19
  T54; 21, 22
  threat 54–55, 57, 61–62, 63–65, 152
tanks, Swedish: S-Tank 22, 106, 112
tanks, Syrian 31
tanks, US 18, 168
  M1 Abrams 130–31, 144
  M60; 22, 30
  T95; 71–72
  XM1; 117, 122, 123
  XM60; 72
Thailand 256
Thermal Imager (TI) 119
Thermal Observation and Gunnery Sight (TOGS) 83–84, 128, 129, 135, 188
TRACER (Tracked Reconnaissance Armoured Capability Equipment Requirement) 245–46, 247
track skirts 47
training tanks 141, **145**
transportation 168, 169
trials:
  Centurion 18, 20, 21
  Challenger 1; 129, 133–34
  Charioteer 57
  Chieftain 76, 77
  Conqueror 44, 48–49, 51
  Warrior 223–24
  see also desert trials; hot weather trials
Tunisia 252
turrets 278–79
  AFVs 234
  Centurion 15, 16–17, 21, 27
  Challenger 1; 135–37
  Challenger 2; 145

  Chieftain 69, **70**, 71–73, 77
  Conqueror 44, 48, 49
  Ferret 256–57, 258–59
  Fox 264, 265
  FV432; 205, **206**
  MBT80; 119–20, 122
  Saladin 251
  Saracen 254–55
  Spartan 184
  Vixen 267
  Warrior 224–25

UK/German Future Main Battle Tank (FMBT) 38, 111–15, 116, 117
United Arab Emirates (UAE) 131–32, 252, 256
United States of America (USA) 101, 103, 172–73
  FSCS (‘Scout’) programme 245–46
  Trilateral Tank Main Armament Evaluation Programme 111, 114
  see also tanks, US
US Army 258

Vehicle Concepts (VC) 245–46
Vickers-Armstrong 20, 72–73
Vickers Defence Systems (VDS) 144–45, 147, 242
Vickers Main Battle Tanks 277–79
Vietnam War (1955–75) 31–32

‘War Office Policy’ (WOP) 172–73
Warrior:
  data 305–7
  development 218–26
  variants 226–32
water cannons 255, 271
weaponry, British 57, 63–66
  AFVs 105–7, 234–35
  Centurion 15–16, 17, 18–19, 20–22, 41–42
  Challenger 1; 134–35
  Chieftain 69–70, 71, 72, 77
  COMRES 75; 104–5, 106, 235–36
  Conqueror 43, 44, 45, 46, 47–48
  Contentious 99, 101–2
  electromagnetic (EM) guns 164
  ENT 159–61
  Ferret 257
  FV433 Abbot 207, **208**, 209
  light tanks 170–71
  MBT80; 120
  Prodigal 103
  Saladin 250–51
  Scorpion/Scimitar 179–80, **187**
  SP70; 274–75
  Warrior 220, 224–25
  see also missiles, British
weaponry, German: 88mm gun 15
weaponry, Soviet 65
weight 104, 150, 163, 168
  Centurion 15
  Chieftain 70–71, 72, 76, 77–78, 84
  Conqueror 45, 50
  CVR(T) 175
Western Desert 14
Wheeled Armoured Vehicle Reconnaissance concepts 261–63
  Fox 263–65, **266**, **268**
  Vixen 265, 267
wheels 45, 76
  Centurion 16, 20, 42
World War II (1939–45) 14, 15, 16, 46

Yemen 252
Yom Kippur War (1973) 30–31, 114

Zadnik, Otto 53